ASTRONOMY®

THE BEST BLACK HOLE IN THE GALAXY

Jupiter: Jewel of the Evening Sky

How to Clean Telescope Optics Safely

March 1992
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ICD 08070

Galactic Grandeur: M83

08070

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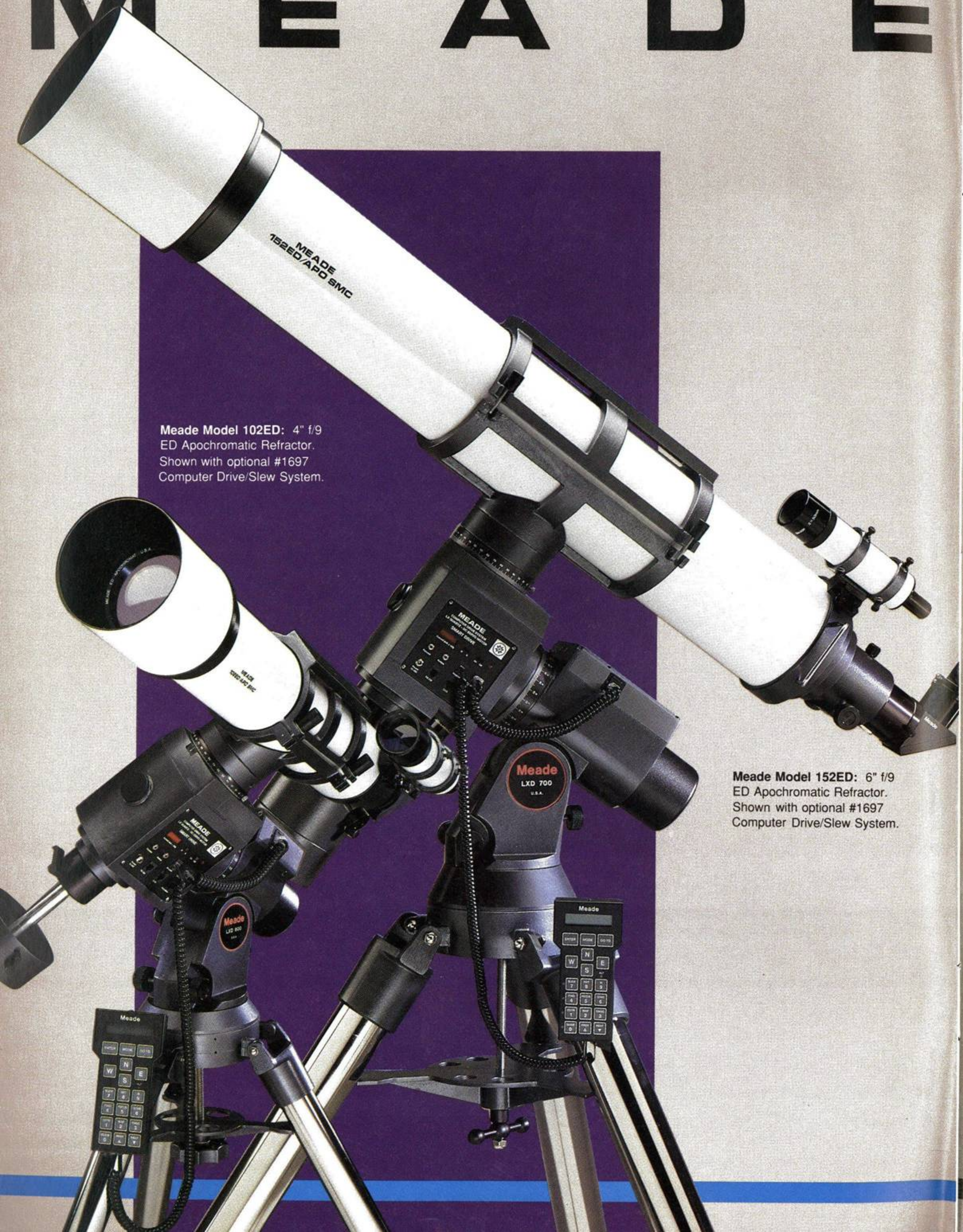
MEADE
152ED/APO SMC
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102ED APO SMC
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LXD 700
U.S.A.
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LXD 600
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Meade Model 102ED: 4" f/9 ED Apochromatic Refractor. Shown with optional #1697 Computer Drive/Slew System.

Meade Model 152ED: 6" f/9 ED Apochromatic Refractor. Shown with optional #1697 Computer Drive/Slew System.

ED APOCHROMATIC REFRACTORS

The most nearly perfect images of the skies obtainable, combined with the most advanced equatorial mounts ever made available.

Have you ever wished you could observe with an instrument that yields the finest, textbook-quality star images obtainable from any telescope? *Now you can.*

Meade USA-made ED Apochromats combine absolutely uncompromised image quality with a level of equatorial mounting precision, stability, and sophistication heretofore only dreamed of by the advanced amateur. *If you're looking for the most nearly perfect, ultra high resolution, high-contrast images of the skies that astronomical instrumentation—of any type—can provide, then a Meade apochromatic refractor is for you.*

Optical Designs—Each 4", 5", 6", and 7" Meade apochromat includes an f/9 objective lens doublet with ED-glass (Extra-low Dispersion) rear element. Corrections for chromatic and spherical aberrations, for coma and astigmatism, and for lateral distortion are as faithful to optimized design criteria as can be obtained in any telescope. The front element of each objective is 2-side **Super Multi-Coated (SMC)** for maximum light transmission and image contrast.

Optical Tube Assemblies include the new Meade #684 giant rack-and-pinion focuser, with eyepiece-holders for both 1.25" and 2". The large 2.7" I.D. focuser sleeve permits the use of either 35mm or large-format professional camera bodies.

High-Contrast Baffling—Every Meade apochromat main tube includes a series of ***ten or more*** internal field stops and light baffles that effectively eliminate any stray light reaching the focal plane. Images of breathtaking sharpness, resolution, and contrast leap out against an extremely dark-sky backdrop.

Equatorial Mountings—As important to the serious observer as superb imaging performance, all-new state-of-the-art Meade LXD 600 and LXD 700 equatorial mountings will revolutionize forever the way amateur astronomers think about telescope mounting platforms. Consider:

- Massive polar and declination castings with oversize thrust surfaces.
- Worm-gear tracking and microfine manual slow-motion controls in both RA and Dec.
- *Eight* sealed ball bearings *(4 on each axis!)* carry even heavy loads with supreme precision.
- Superstable field tripods, including a new Meade Giant Field Tripod with 6" and 7" APO models.

MEADE ED APOCHROMAT U.S.A.
D = 102mm
F = 900mm f/9
MULTI-COATED

MEADE
COMPUTER DRIVE SYSTEM
LX QUARTZ - DC SERVO MOTOR
SMART DRIVE
Current (mA x 100)
Focuser
Reticle
N S
On Off
Power 12 VDC
RS 232
Keypad
RA Motor
CCD
Encoders

Optional Electronic Drive Systems—Two new dual-axis, DC-servo-motor-controlled electronic drive systems are available for the LXD 600 and LXD 700 mounts; both drive systems fully integrate internally to either mount:.

■ ***#1697 Computer Drive/Slew System:***

Four dual-axis drive speeds for (a) photo-guiding corrections (at **2x** sidereal rate); (b) image centering and microslewing in the main telescope (at **32x** sidereal rate); (c) image centering in the viewfinder (at **2° per second**); and fast-slewing of the telescope across the skies (at **8° per second**). Use the keypad controller to switch speeds instantly as you move the telescope electronically with a pointing accuracy never before available.

Permanently programmable (PPEC) Smart Drive™ capable of reducing RA periodic drive errors to 5 arc secs. or less.

Digital Readouts on both telescope axes, read from the handheld Electronic Command Center.

GO TO Capability: Enter the RA and Dec of an object, punch GO TO, and the telescope automatically slews on both axes at 8° per second to the object, centering it in the field.

747-Object Built-in Library: Enter any of the 110 Messier objects, 278 of the finest NGC objects, 351 stars (doubles, variables, polar alignment stars), or one of the 8 major planets from Mercury to Pluto; punch GO TO, and the telescope automatically slews to the object. For $99* add the optional Meade 8000-object CNGC library to the software (a 30-second plug-in).

Keypad operation of virtually every telescope function, from tracking rates to the crossline brightness of an illuminated reticle eyepiece.

Polar alignment of the Mount: Quick (less than one minute) and precise, using the 2-star method.

■ ***#1664 Electronic Drive System***—For users not requiring the microprocessor-controlled capabilities of the #1697 Computer Drive, the #1664 system* includes 2 dual-axis drive speeds (**2x** and **32x**); permanently programmable (PPEC) Smart Drive; object tracking-rate control, including quartz-controlled sidereal rate; and other features.

Complete ED Apochromatic Refractors

Specifications—Each complete telescope includes: optical tube assembly with #684 giant 2.7" focuser, 8 x 50mm viewfinder, #930 2" diagonal mirror with 1.25" adapter, and Super Plössl 26mm eyepiece; 4" and 5" models include the LXD 600 equatorial mount and standard field tripod; 6" and 7" models include the LXD 700 equatorial mount and giant field tripod; each mount is provided with manual slow-motion controls, analog setting circles, and locks on both axes.

Special Introductory Pricing Through 5/31/92*:

Model 102ED:	4" f/9 ED/APO complete	**$1795.**
Model 127ED:	5" f/9 ED/APO complete	**2295.**
Model 152ED:	6" f/9 ED/APO complete	**3995.**
Model 178ED:	7" f/9 ED/APO complete	**4995.**

Drive Systems

#1664	Electronic Drive System	**$295.**
#1697	Computer Drive/Slew System	**595.**

Optical Tube Assemblies (OTA's)

Each OTA includes complete tube assembly with #684 giant 2.7" focuser. Supplied without viewfinder or accessories.

Model 102ED/APO-OTA:	4" f/9	**$1075.**
Model 127ED/APO-OTA:	5" f/9	**1595.**
Model 152ED/APO-OTA:	6" f/9	**2295.**
Model 178ED/APO-OTA:	7" f/9	**2995.**

Equatorial Mountings

LXD 600 Mount & Standard Field Tripod	**895.**
LXD 700 Mount & Giant Field Tripod	**1995.**

■ *Prices shown are suggested USA mail-order retail prices and do not include sales taxes or shipping, if applicable.

■ The 1992 Meade General Catalog—$3.00 postpaid—is available from any authorized Meade dealer or directly from Meade Instruments.

■ **For further information on Meade ED Apochromatic or Schmidt-Cassegrain telescopes, or on any Meade product, call Meade Instruments toll-free at 1-800-854-7485 (in Calif. 714-556-2291), or contact one of these authorized mail-order dealers:**

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Orders: 800-843-4780; Info.: 818-505-8424.

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ON THE COVER: The graceful spiral arms of galaxy M83 in Hydra wrap gently around a bright nucleus. Amateur astronomers are producing detailed images of galaxies like M83 with the help of better films and automatic guiders. The story on page 68 describes how amateurs are "going deep" for galaxies. Photo copyright Anglo-Australian Telescope Board.

THE SKY EXPLODED with color on November 8 when an aurora filled the sky. This display, one of the best the last few years, was seen in the early evening over most of Canada and the United States. For more about aurorae turn to page 38. Photo by R. B. Slobins of Colesville, New York who focused on zenith to capture the converging auroral rays.

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The Audit Bureau

Behind the Scenes

HOW DO YOU FIND A BLACK HOLE?

What is it about black holes that so captures the public imagination? To hear people talk, these things are everywhere — in traffic jams, the postal system, maybe even that hidden place where all lost socks go. No one, it seems, can do without black holes.

But ironically, if the general public has embraced them with gusto, astronomers themselves have been tougher to convince. After all, they say, how can you *prove* the existence of something you can't see or touch, something that lies unreachably far away? The observational difficulties, plus astronomers' innate skepticism and demand for rigorous proof, have created quite a list of candidate black holes that failed to make the grade.

The searching may finally be over. As Ken Croswell says in his story beginning on page 30, many astronomers now believe they have an ironclad prospect. It's a faint binary star system, an obscure object in Monoceros that carries the cryptic designation A0620–00. Reading this astronomical detective story, I got a wonderful sense of how astronomers closed in on their quarry by eliminating one plausible alternative after another until the only choice left was — a black hole.

A different sort of astronomical mystery appears to be just unfolding. New results from NASA's orbiting Gamma Ray Observatory hint that bursts of gamma rays — highly energetic events whose source is almost wholly unknown — are coming from immense distances in space. But how far away? And what is triggering these outbursts which have baffled theorists? Rich Talcott's up-to-the-minute report begins on page 54.

Moving into our own cosmic backyard, this month is the ideal time to ready your telescope for Jupiter. At opposition on February 29, the giant planet becomes an outstanding "jewel" in the evening sky during March. You're in good hands with long-time Jupiter observer José Olivarez, who will show you just what to keep your eye on (see page 85). And if that telescope needs a bit of a tune-up to get the most from Jupiter, look no farther than page 81. That's where you'll find complete directions on how to clean those dusty, dirty optics — and do it safely.

As spring returns to the Northern Hemisphere, it's time to shake off any lingering winter blahs and begin exploring the wonders of a new season's skies.

Sincerely yours,

Robert Burnham
Senior Editor

ASTRONOMY

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Letters

Do You Remember . . .

Ken Croswell's article "Will the Lion Roar Again?" (November 1991 issue) about the Leonid meteor shower reminded me of a memorable shower I saw from the Presidio in San Francisco. Unfortunately, I don't remember when the shower occurred. It was sometime in the fall of 1946 or the following winter. — *P.O. Abbott, Pueblo, Colorado*

— *You most likely saw the Draconids on the night of October 9/10, 1946. This meteor shower was the first to be detected by radar.*

Speeding Pulsar Planet

The motion of the pulsar planet described in "First Planet Beyond the Solar System" in the December 1991 issue has me puzzled. You state the orbital velocity of pulsar 1829–10 as 3000 kilometers per second. However, if a planet orbits at 0.71 astronomical unit, its speed is only 42 kilometers per second. How can the pulsar move at such a high speed? — *Zdenko Saroch, Sarnia, Ontario, Canada*

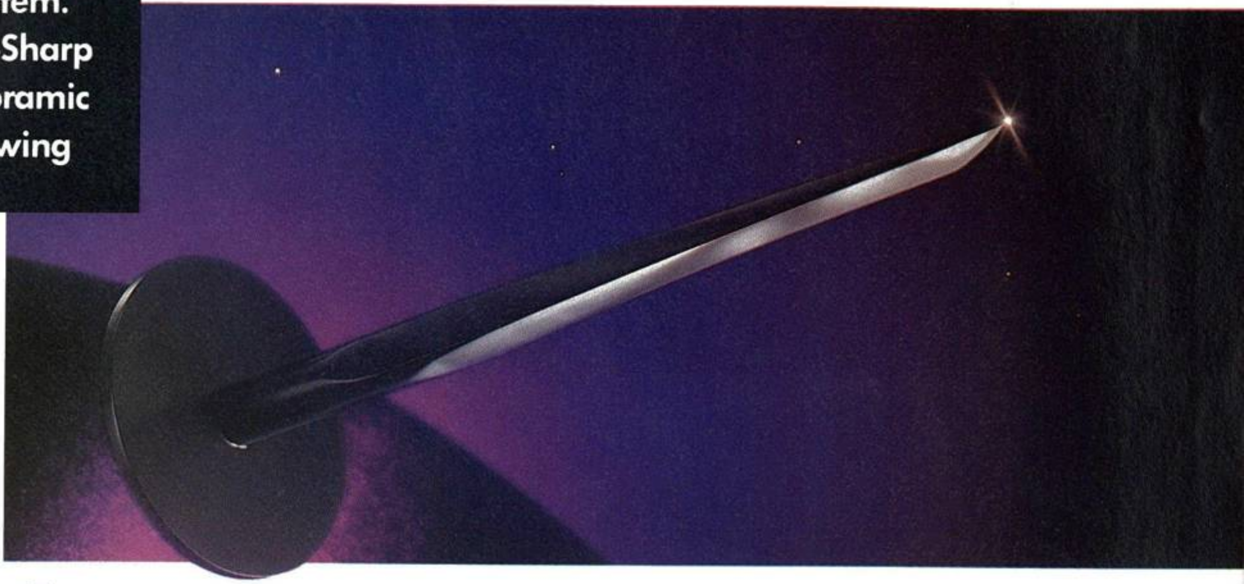
— *What was mistakenly attributed as the pulsar's speed was the displacement toward or away from us. Lyne and colleagues interpreted changes in the timing of the pulsar's radio pulses to be a result of the pulsar's displacement. This displacement, 3000 kilometers, is essentially the radius of the pulsar's motion about the center of mass of the pulsar-planet system. The pulsar has a stately orbital speed of roughly 1 meter per second.*

Buying Your First Telescope

The insert in the November issue on "How to Buy Your First Telescope" was the first purchasing guide I have seen in a long time that I felt was up-to-date, informative, well balanced, and objective. One point that I thought should have been added is advice to attend a star party hosted by a local club. Star parties offer a wonderful opportunity to prospective buyers to try out many different types of equipment under actual operating conditions. One can talk with other amateurs to find out why they purchased their particular model of telescope. Star parties are also a good

PANOPTIC

Tele Vue Panoptic™ Eyepiece System. Tack-Sharp Panoramic Viewing



Another step toward the "spacewalk" experience. Using very high index glasses, Al Nagler's new design has dramatically extended low-power eyepiece performance. Panoptic has far more tack-sharp imagery than any eyepiece in its class. The 68° apparent field 35mm (2"), and 22mm (2"/1¼") models feature grip rings, eyeguards, and new protective lens caps. When used with the Tele Vue 2x Big Barlow and the new Panoptic interface lens, you obtain 17mm and 11mm focal lengths with image quality rivalling the revolutionary Nagler eyepieces. All this with plenty of eye-relief. For eyeglass wearers, there's no better choice. The Panoptic eyepiece system by Tele Vue. Even better than you imagined!

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35mm
PANOPTIC™

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GENUINE MEADE ACCESSORIES & PARTS

Series 4000™ Eyepieces, Filters, and Barlows

1 The World's finest telescope eyepieces now include rubber grips and soft rubber eyeguards for an even better observing experience! All eyeguards fold down for eyeglass wearers—a feature not available on competing brands. Best of all, **Meade Series 4000's are guaranteed to deliver more field, more contrast, and more image sharpness than any other brand at any price, or your money back.*** For splitting the closest doubles, revealing tenuous, faint nebulosity in deep-space, or studying hairline lunar and planetary detail, Meade multi-coated Series 4000's are the oculars that serious observers insist upon. ***"Clearly the best."***

Super Plössls (5-elements; 1.25"; 52°):
6.4; 9.7; 12.4; 15; 20; 26mm ea **$79.95** (2.49)
32mm(52°); **40mm**(44°); each **99.95** (2.49)
56mm (52°, 2") **219.95** (3.18)

Super Wide Angles (6-elements; 1.25"; 67°):
13.8mm: 129.95 (2.49) **18mm: 139.95** (2.49)
24.5mm: 159.95 (2.49) **32mm**(2"): **229.95** (3.18)
40mm(2"): **279.95** (3.18)

Ultra Wide Angles (8-elements, 1.25"; 84°):
4.7mm: 147.95 (2.49) **6.7mm: 187.95** (2.49)
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14mm(1.25"/2"): **249.95** (3.18)

*at participating dealers; see catalog for details.

2 **#140: Series 4000 2x Apochromatic Barlow Lens** (1.25")--The original Meade 3-element, air-spaced, multi-coated design. Absolutely unmatched in image resolution and color correction. 28mm dia. lens (26mm clear aperture). **$69.95** (2.49)

3 **Series 4000 Photo-Visual Color Filters** (1.25")—Made of purest crown optical glass, dyed in the mass. For increased contrast on the Moon and planets . Thread into virtually all 1.25" eyepieces sold today. Fully coated.

#8 Lt. Yellow; #11 Yellow-Green; #12 Yellow; #21 Orange; #23A Lt. Red; #25A Red; #38A Dark Blue; #47 Violet; #56 Lt. Green; #58 Green; #80A Blue; #82A Lt. Blue.
each **$12.95** (1.79)

Set #1—4 filters: #12 Yellow, #23A Lt.Red, #58 Green, #80A Blue **$42.95** (2.49)

Set #2—4 filters: #11 Yellow-Green, #25A Red, #47 Violet, #82A Lt. Blue **$42.95** (2.49)

Set #3—4 filters: #8 Lt. Yellow, #21 Orange, #38A Dark Blue, #56 Lt. Green . **$42.95** (2.49)

Sets #1 & #2—8 filters **$82.95** (2.49)

Sets #1, #2, & #3—12 filters **$118.95** (3.18)

4 **Series 4000 Moon Filter** (1.25")—Excellent for 4" to 12" telescopes. Reduces Moon brightness by 87%. **$14.50** (2.49)

5 **Series 4000 Nebular Filters**—The very latest in multi-layer interference coating technology, Meade premium nebular filters are guaranteed to be the finest obtainable at any price. Use a Series 4000 Broadband filter to block most forms of light pollution, with minimal attenuation of desired wavelengths. Use a Narrowband filter in heavily light-polluted areas, or for extremely high contrast observing of faint nebulae.

BROADBAND FILTERS

#908B (1.25")—Threads into all Meade 1.25" eyepieces, and virtually all other brands. Full 26mm clear aperture. **$67.95** (1.79)

#910B—Threads into all Meade 2" eyepieces and most others; 44mm dia. **99.95** (2.49)

#911B--Threads on to the rear cell of Schmidt-Cassegrain telescopes. **87.95** (1.79)

NARROWBAND FILTERS

#908N (1.25")—Threads into virtually all 1.25" eyepieces; 26mm clear aperture. **89.95** (1.79)

#910N—Threads into all Meade 2" eyepieces and most others; 44mm dia. **119.95** (2.49)

#911N--Threads on to the rear cell of Schmidt-Cassegrain telescopes. **109.95** (2.49)

World's Most Advanced Illuminated Reticle Eyepiece

Series 4000 Plössl 9mm, with rubber eyecup and micrometric X-Y positioning of the reticle within the field. Greatly facilitates locking on the guide star. Sharp high-power imaging, excellent eye relief. Wireless red LED illuminator with adjustable brightness control. Internal batteries included. Multi-coated optics. Bullseye reticle. 1.25"
$119.95 (2.79)

Series 4000 Plössl 9mm—Same as above but with 6 ft. cord and plug for Meade LX3, LX5, LX6, LX100, LX200, and APO power panels, in place of wireless illuminator. **$99.95** (2.79)

MA 12mm Illuminated Reticle Eyepiece

Excellent 3-element optical system, long eye relief, fully coated, with double crossline reticle. Includes wireless red LED illuminator with internal batteries and variable brightness control. **$89.95** (2.79)

MA 12mm-Same as above, but with cord and plug for Meade telescopes with power panels, in place of wireless illuminator.
$69.95 (2.79)

2" Diagonal Mirror

#929: Permits use of wide-field 2" oculars. Threads on to rear cell of Meade and Celestron SCT's. Includes multi-coated precision optical flat made at the Meade factory; with 1.25" eyepiece adapter **$89.95** (2.79)

Camera Adapters (1.25" & .965")

Professional-quality adapters for rigid coupling of telescope-to-camera. Use for either Eyepiece-Projection or Prime Focus. Precision-machined of aluminum and brass, threaded for filters. Use with T-Mount, available separately.

.965": $24.95 (2.49) **1.25": $29.95** (2.49)

Variable-Projection Camera Adapter (1.25")

Machined sliding cell allows variable projection power in eyepiece-projection photography; permits precise selection of correct photo power in lunar and planetary photography; threaded for filters. Use with T-Mount for your camera. **$39.95** (2.49)

Tele-Extenders

For Eyepiece-Projection photography with any Meade or Celestron SCT. Threads on to eyepiece-holder. Use with T-Mount for your camera.

Basic Tele-Extender: *(above)* Fixed projection power; use with eyepiece for lunar and planetary photos. **$26.95** (2.49)

Variable Tele-Extender: Sliding cell, with lock, permits wide range of projection magnifications with the same eyepiece.
$36.95 (2.49)

T-Adapters for SCT's

For Prime Focus photography with any Meade or Celestron SCT. Use with T-Mount for your 35mm camera.
$26.95 (2.49)

2X Telenegative Barlow (1.25")

#122: Doubles eyepiece power with sharp, high-resolution, high-contrast imaging on telescopes of all types. 27mm dia. (26mm clear aperture). Excellent corrections for chromatic and spherical aberrations at all photo-visual wavelengths. Multi-coated. 1.25" **$47.95** (2.49)

2x-3x Variable Barlow (1.25")

#127: Precision internal sliding lens assembly permits continuously variable power settings between 2x and 3x. Engraved scale indicates power in use. Yields bright, sharp, high-contrast images on telescopes of all types. Multi-coated, 1.25" **$59.95** (2.49)

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Fine 4-element oculars that yield excellent image quality with any telescope. Computer-optimized design provides wide, flat fields, highly corrected for spherical and chromatic aberrations. Parfocal, multi-coated, 1.25" barrels. Threaded for filters. **Focal Lengths: OR 4, 6, 9, 12.5, 25mm.**
each **$47.95** (2.49)

Modified Achromatic Eyepieces

An improvement on the traditional Kellner design, the 3-element MA gives sharp, faithful, well-corrected images of the Moon, planets, and deep-space. Multi-coated; threaded for filters. 1.25". **Focal Lengths: MA 9, 12, 25, 40mm.**
each **$37.95** (2.49)

Rack-and-Pinion Focusers (1.25")

The finest focusers in the industry, Meade rack and pinion mechanisms have precise, ultra-smooth action along the entire travel distance. Housings are machined for tight fit of the moving sleeve. All focuser models may be used on tubes of from 4" to 20" diameter; all accept 1.25" eyepieces. Mounting hardware included.

#71—The finest economical focuser available. Travel distance: 2.2". A precision mechanism, beautifully finished. **$44.95** (2.49)

#67—Includes spring-loaded gearbox for variable tension adjustment. Travel distance: 2.2". **59.95** (2.49)

Rack-and-Pinion Focusers (2")

#680--The most popular 2" focuser ever manufactured. Thousands in use. Spring-loaded gearbox; 3" travel. Includes 1.25" and 2" eyepiece-holders. **89.95** (3.48)

#682—Low-profile 2" focuser; body height only 1.75". Spring-loaded gearbox. Travel: 2.5". Includes 1.25" adapter. **99.95** (3.48)

Viewfinders: 30mm, 50mm, 60mm

#637: 6 x 30mm-Fine, 7° wide-field finder; coated, achromatic lens; crosshair eyepiece, 2-ring bracket with alignment screws. Attaches to tube diameters 6" to 12" **$39.95** (2.79)

#545: 8 x 50mm-*(lower photo)* Wide 5° field; coated achromatic objective; crosshair eyepiece. White tube. Ideal for telescopes of any aperture. See bracket below. **59.95** (3.48)

#544: 8 x 50mm--Same as #545, but in Meade blue. **59.95** (3.48)

#957: 9 x 60mm--*(top photo)* Collects 44% more light than 50mm; superior for faint objects, bracket below. **89.95** (3.78)

Bracket for 8 x 50mm: Fits Meade and Celestron SCT's, and other tubes from 7" to 20" diameter. **17.95** (1.79)

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Superb, fully multi-coated 11 x 80mm and 20 x 80mm Giant Binoculars, ideal for wide-field deep-space observing. **Rubber-coated bodies for rugged field use!** BAK-4 prisms yield bright, sharp, high-contrast images. Hard carry case, tripod adapter included.

11x80: $359.95 (4.87)
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45° Erect-Image Diagonal Prisms

Originally developed by Meade Instruments, these convenient diagonals erect the astronomical image, for terrestrial use of astronomical telescopes. Fully coated.

#927: for .965" focusers.
#928: for 1.25" focusers.
#931 Hybrid: accepts 1.25" eyepieces, fits .965" focusers.

Specify model desired. each **$49.95** (2.49)

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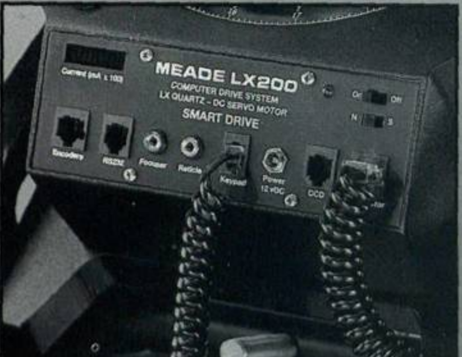

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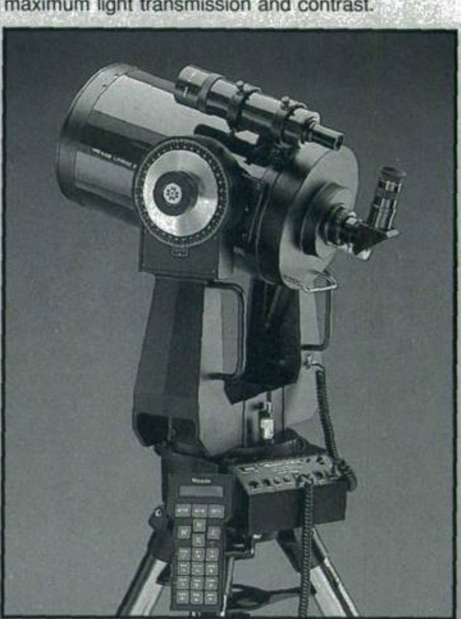

Altazimuth Mode Operation—For all visual observing applications, and for lunar and planetary photography, Meade LX200's may be set up in the altazimuth mode, without any equatorial wedge—just attach the telescope's drive base directly to the tripod, use the fast 1-star alignment procedure, and the telescope's computer actuates 2-axis tracking that keeps objects precisely centered in the field, even at high powers, during the entire observing session. For long exposure photography (longer than about 5 minutes) altazimuth-induced field rotation requires an equatorial wedge, which may be purchased separately.

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MEADE LX100 SCHMIDT-CASSEGRAINS

Observers not requiring the sophistication of the LX200 electronics may wish to consider an 8" or 10" LX100 model SCT instead. Meade LX100's include the exact same heavy-duty fork mounts of their LX200 counterparts, but with a microfine declination tangent arm control in place of the LX200's motorized worm gear, and with a 2-speed drive in place of the LX200's 4-speed drive; optical tubes and coatings are identical. Standard LX100 features include:

■ Handheld Electronic Command Center—With 2-speed operation, **2x** for photo-guiding and **32x** for image centering and microslewing in the main telescope. (With the optional DC-servo declination motor installed, these speeds are operational on both telescope axes.)

■ Permanently programmable (PPEC) Smart Drive, as described above.

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■For dealer or catalog information see the Meade **ED Apochromatic Refractor** ad in this issue.

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place to obtain leads on used equipment. They are a golden opportunity to try before you buy. — *Ray Spreier, Bend, Oregon*

Venus in Oregon?

The photo of Venus' "Tick Mons" on page 36 of the September 1991 issue ("Venus: Planet of Fire" by Robert Burnham) reminds me of the caldera at Crater Lake National Park in Oregon. On the inside slopes of the crater, you can see radially oriented structures resembling those of Tick Mons. These features formed when pressure prior to the last eruption cracked the rock inside the mountain and lava filled the cracks. Continued build-up of pressure eventually blew off the top of the mountain, leaving behind the two-mile-wide crater. Rain and melting snow washed the loose rock on the sides of the crater down into the lake that formed at the crater's bottom. The hardened lava produced in the pressure cracks was left standing around the inside of the crater. Perhaps the structures surrounding Tick Mons formed in a similar way, albeit with a different erosion mechanism. — *Tomas Rodriquez, Cali, Colombia*

Thanks!

I am happy to have won a telescope in your monthly subscription renewal drawing. It's like winning a lifetime ticket for a trip around the universe, with ASTRONOMY as the perfect traveling companion. Thank you for helping me to explore the beauty of other worlds. — *Rosalind Yanishevsky, Polebridge, Montana*

Explaining Our Solar System Map

Could you please explain the solar system map that appears at the end of the Sky Almanac section? — *Howard Gralnick, Sayville, New York*

— The map at top displays the entire sky visible from dusk (at right) to dawn (at left). The center of the map is the part of the sky directly south at midnight on the 15th of the month. The darker bands at the right and left of the map show those areas of the sky lost in the twilight glow on the 15th of the month as seen from 40 degrees north latitude.

The positions of the Sun and each planet on the 15th of the month are shown by a dot. If the object moves quickly through the sky, an arrow shows the motion from the first day to the last day of the month. To find the phase and the position of the Moon for a given day, look at the row of Moons at the bottom of the map. This shows the phase of the Moon for each day. By drawing a line straight up to the path of the Moon (shown as a red line), you can find out where the Moon will appear that day.

The middle of the page gives, for the day listed, observing data on each planet and the telescopic view (with south at the top and east to the right). The diagrams show the relative sizes of the planets, their apparent phases, and the orientations of their poles and equators.

Jupiter's Moons (in the bottom left corner) gives the positions of the four Galilean satellites as seen through a telescope for each day of the month. The dots show the satellites' positions at the time listed, while the lines show the positions at all other times.

The Planets in their Orbits shows the positions of the planets in their orbits if we looked down from above the solar system. The left side shows the inner planets, with arrows showing the planets' motions during the month. The right side shows the orbits of the outer planets. The orbits of Mars and Jupiter would be tiny if all the orbits were drawn to scale, so we show arrows to indicate the directions to the three outermost planets. The other planets move so slowly that their position along their orbit is simply marked with a dot. Both diagrams are oriented so Earth appears at left at the time of the vernal equinox (about March 21).

Astronomy Educators

The Association of Astronomy Educators (AAE) is a group dedicated to improving astronomy education at all levels, from kindergarten through college. The association publishes a journal called *Astronomy Education* which contains information about effective curricula, materials, and activities. The AAE is affiliated with the National Science Teachers Association and is a co-sponsor of Astronomy Day. For more information, contact Chaz Hafey, Universe Planetarium, Science Museum of Virginia, 2500 West Broad Street, Richmond, VA 23220. □

ASTRONOMY welcomes comments and additional information on articles and astronomy in general. Send your letters to ASTRONOMY Letters, P.O. Box 1612, Waukesha, WI 53187-1612. Letters may be edited for length or clarity.

ASTRONOMY TALKS WITH A GREAT PLANETARY OBSERVER

by James Phillips

I became interested in amateur astronomy in the mid 1960s. At that time I came across spectacular pencil drawings of the Moon published in *Sky & Telescope*. The drawings were the product of an observer named Alika Herring, who used a 12.5-inch Newtonian reflector. I was amazed by the amount of detail he was able to see and the overall beauty of the drawings.

After that time I didn't hear of Alika for some years, until I began the new lunar dome survey for the Association of Lunar and Planetary Observers (ALPO). I was quite amazed and excited when I received a letter from him requesting information on the survey. Since then, Alika has contributed more telescopic observations to this program than all of the other observers combined. Because of his pioneering work in visually observing the Moon, I recently interviewed Alika about his work.

ASTRONOMY: In 1966 you first published drawings of the Moon including the interior details of the craters Copernicus and Encke and the mountain peak Pico. Can you tell us a little about this early period?

Herring: I used a 12.5-inch Newtonian. I started the drawings more or less for fun and at some point I met Charlie Federer, at that time the editor of *Sky & Telescope*. He suggested that I contribute some drawings, and my first one was published in July 1958. These drawings were really intended to stir up interest. It is questionable how much scientific value they had.

ASTRONOMY: They certainly did stir up *my* interest. How do you get details like the shading right?

Herring: It takes quite a bit of practice. It depends on the kind of paper you're using.

ASTRONOMY: What do you recommend?

Herring: I experimented with different papers over the years and I ended up with Pinehurst White Vellum, 2-ply bristol. It comes in large sheets which I cut down to 8-1/2" x 11". After I finish a drawing, I file it away in a looseleaf binder. That's where I have all of my originals.

ASTRONOMY: Do you spray them with a fixative afterwards?

Herring: I give them several light coats of clear acrylic. After that dries I get some plastic and cover them. The drawings look just as fresh as the day I made them.

ASTRONOMY: What type of pencils do you use?

Herring: Just ordinary lead pencils, usually a #2.

ASTRONOMY: Your results are outstanding. How did you get started in amateur astronomy?

Herring: When I was 9 or 10 I started making my own telescopes out of old spectacle lenses. I used to haunt the spectacle shops and they would give me old lenses and I would take them home and try them out. I found one good lens that had about a one-meter focal length. I was able to make a little telescope out of that and could see craters on the Moon with it.

I started out as a typical amateur, I guess. I was interested in the deep-sky stuff. I would read the astronomy books and see all the pictures of the nebulae and star clusters and that created an urge to look at them. When I did look at the Moon and planets, I didn't really have good optical quality to see much detail. When I was about 11 or 12, I got an old box camera, a Kodak Brownie, and knocked the lens out of it. By that time I had acquired a small telescope that was commercially made and I was able to put the camera behind the telescope. By using the projection method I was able to get some lunar photographs. When I was 13, I got hold of the first edition of *Amateur Telescope Making* and with that I was able to make a 6-inch mirror. I silvered it in the high school chemistry lab and my Dad helped me make a simple mounting for it. That was my first real telescope.

ASTRONOMY: You ended up with a 12.5-inch reflector. I noticed when I became interested in amateur astronomy that a great many of the experienced lunar and planetary observers used 12.5-inch reflectors. Is there any particular reason why you use a 12.5-inch instead of a 10-inch or 14-inch reflector?

Herring: Well, I think basically it is just a matter of finances.

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Herring: If I could have gone to a 24-inch scope, I would have.

ASTRONOMY: What are your thoughts about increased aperture resulting in increased turbulence?

Herring: Your seeing at any given time will tend to worsen as you increase aperture. When you are looking at a star, the surge of light that the telescope is picking up has much turbulence in it. If you increase the size of that cylinder of light by increasing aperture, you increase the amount of turbulence.

ASTRONOMY: Does the aperture make up for the fact that there is some increase in turbulence?

Herring: Yeah, but the point is that as you increase aperture you also increase resolution.

ASTRONOMY: So you catch those times when seeing sharpens up for you and what you can see with the bigger aperture makes up for having to deal with more turbulence.

Herring: Right.

ASTRONOMY: Do you have any idea of the finest detail you have seen on the surface of the Moon?

Herring: I have worked on the crater Plato very considerably. I think the smallest craters inside Plato that I have seen with a 12.5-inch have been smaller than 2,000 feet across.

ASTRONOMY: Do you believe that there are new things to be discovered on the Moon?

Herring: Oh, absolutely! And there are lots of questions I wish I could answer. For example, a region of interest is the dome field near Marius. Now there are several intriguing questions about these domes. Why are they all concentrated in one particular area? How did they form? The Moon is different from Earth. On Earth just about all the features that we have, mountain ranges and so forth, are the result of what we call plate tectonics — giant crustal plates moving around and grinding against each other. We don't have any plate tectonics on the Moon. So there are questions as to how these dome features form. Most other lunar features resulted from impacts.

ASTRONOMY: Thinking back over your observing career, would you do anything differently?

Herring: I think if I had to do it over again, I would start work on the Moon much earlier than I did. I didn't really get serious until I moved to California in 1952 from Ohio. I belonged to the American Association of Variable Star Observers, and I contributed variable star observations. I was in an area where I had a nice clear dark sky, but after I moved here I had a murky atmosphere. I have never seen the Milky Way from this location.

ASTRONOMY: But you do get good seeing.

Herring: We occasionally get some very good seeing. So that's when I really started on the Moon in earnest. I felt a little silly when I first came out here trying to observe variable stars with a 12.5-inch scope that guys were viewing elsewhere with a 3-inch telescope.

ASTRONOMY: You mentioned that you have done a lot of work with Plato. Any particular favorite objects on the Moon or areas that you enjoy?

Herring: Well, I guess over the years I have observed Plato more than any other. Plato over the last century has been a pretty popular object.

ASTRONOMY: You worked with mapping the Moon with the Lunar and Planetary Laboratory in Arizona.

Herring: Yeah, I covered the whole limb.

ASTRONOMY: What was the purpose of the mapping?

Herring: They were published in the *LPL Communications.* About that time, in the 1960s, the lunar orbiter spacecraft photos came out and pretty well killed it. It was going to be published as a supplement to the rectified lunar atlas. These were rectified drawings of the lunar limb. Do you understand the process?

ASTRONOMY: Please tell us.

Herring: What you do is take a blank globe, about three feet in diameter. We took photographs of the Moon and we projected them onto the globe. Then you can stand by the globe and photograph the limb regions from directly above.

ASTRONOMY: To get an idea of what the features really look like.

Herring: Right. In other words, something like Plato, if you projected a photograph of the Moon onto the globe and then you photograph Plato from a vertical point, Plato becomes circular. It does introduce quite a bit of distortion in other ways, so your shadows are stretched out. I took these rectified photographs and redrew them. I made a drawing of the area, most of the time having to interpret just what the detail was that we were seeing. It was really quite a tricky project.

ASTRONOMY: Do you use filters for lunar observing?

Herring: The only real filter that I

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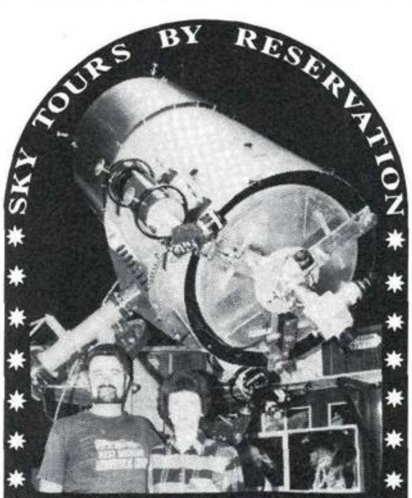

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have used on the Moon has been a polarizing filter. The Moon is bright and the polarizing filter will knock the illumination down considerably. It also has one other advantage.You put it on the telescope, and you can use it in the late afternoon while the Sun is still up. You can rotate the thing until you get the polarization effect and darken the sky. The Moon will stand out nicely. It enables you to do some observing in the late afternoon.

ASTRONOMY: Every time I have tried to observe in the late afternoon, even though the Moon is visible with the eye, I don't get enough contrast.

Herring: You will find the polarizing filter will help you get more contrast in the daylight. I have some filters I have had for years. I got these little photo filters, 1" diameter, and some plastic bottle caps that would just fit over the eyepiece. I drilled a hole in the top of the cap so I could look through it and wedged the filter inside with pieces of cork to hold it in. The cap easily slips on and off the eyepiece.

ASTRONOMY: That's very innovative. I have always had a problem trying to mesh an observing program with work and family. Obviously observing a lunar feature under varying lighting conditions requires you to observe it at odd hours of the night.

Herring: I would generally lose a little sleep.

ASTRONOMY: You would wake up at the appointed hour and observe what you needed to observe?

Herring: Right. The family was very understanding. They didn't mind my being out in the backyard with the telescope. They always knew where I was.

NAVIGATING THE CELESTIAL HOT TUB

By Beverly Mosier

After much careful thought, we enrolled in our local college's class on celestial navigation. But why? We soon noticed that our fellow students either already owned yachts capable of sailing at least to Hawaii, or had been building boats for a number of years and now, about finished, were eager to embark on long dreamed cruises to the unknown. A couple of hearty young men had obtained good paying summer jobs on fishing boats. These people, at least, all had perfectly logical reasons to be there. They were preparing themselves for life or death struggles with the open sea.

On the other hand, our two small boats lying on the sand below the deck at home (one a row boat for fishing, the other a catamaran, sort of a beat-up trampoline with pontoons) were clearly meant for staying close to shore. If we should find ourselves in need of navigation for either, we would definitely require the services of the Coast Guard. So why were we spending two nights a week studying celestial navigation? I think it was the word *celestial*. It has such a nice ring to it. It fairly jumped right off the pages of the school catalog. So the two of us, Bob and I, decided to enroll. I reasoned: You never know when we might be tempted to take a Love Boat cruise. Remember the *Titanic*?

The first thing I noticed, after paying my tuition and investing in the books and equipment, was that the three very large textbooks seemed to contain more numbers than letters. Oh, *oh* — this is going to be a long semester! The second thing I discovered was that celestial navigation lent itself very well to Hot Tub study. Maybe it wouldn't be so bad after all. Luckily, we found ourselves in the hands of an excellent teacher who had, besides an interesting teaching manner, years of experience sailing around the world and an inexhaustible supply of breathtaking sea stories. These, of course, were intended to make us understand the importance of studying lessons well.

The first thing we learned was that from now on we had to suspend belief in all we had learned about astronomy. From that day on we would remember that Earth is in the center of the universe and all bodies — Sun, Moon, planets and stars — are rotating around us. We were now on the terrestrial sphere and all else was on the celestial sphere. What we would learn to do is measure the distance of a given star or planet above the horizon. We would accomplish this with the help of newly issued sextants and our copies of the *Nautical Almanac.* By finding the star on our charts and plotting its altitude, we could determine just where on Earth we were. Sounds simple enough!

"Failing that," our teacher said, "you can always use the butter method to get to Hawaii." With all

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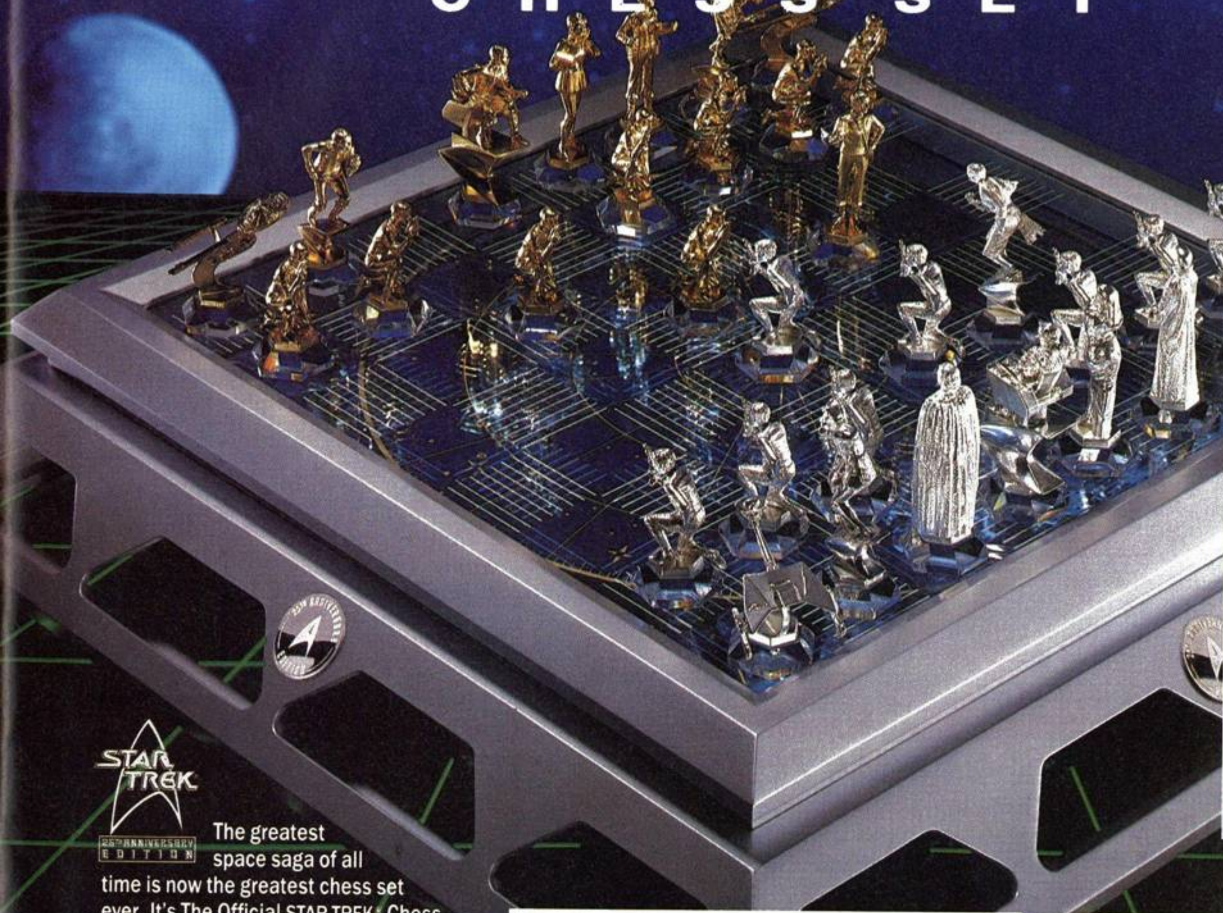

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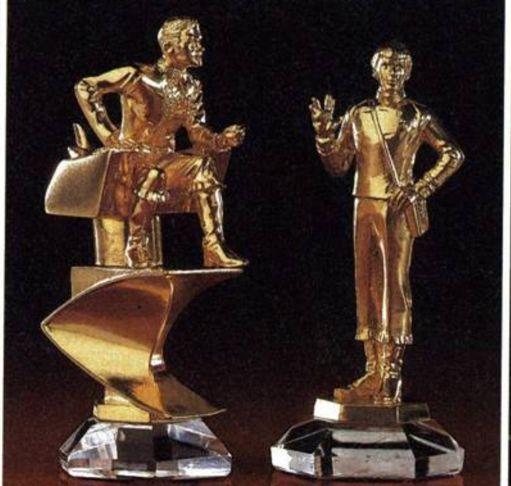

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eyes on him, he continued. "Take the butter out of the icebox and sail south until it melts. Then turn right!" After learning a host of new terms we received a sextant and learned to shoot the Sun at meridian passage (high noon) and to sight the Moon. We accomplished this task from the rocks of the nearby boat jetty and from the school sailboat, a beat-up but apparently seaworthy craft that someone donated for the sake of education. Soon we were ready to learn what I had been looking forward to from the beginning — to sight the stars.

We climbed aboard the good "ship" Hot Tub a little early the next night. Our *Nautical Almanac* contained a chart for each day of the year. And on that day's chart we found the time of the end of civil twilight in our latitude, when the Sun is 6 degrees below the horizon. That is the time we must be prepared to make our star sightings. Before that time it's too light to see the stars and very soon after it's too dark to see the horizon.

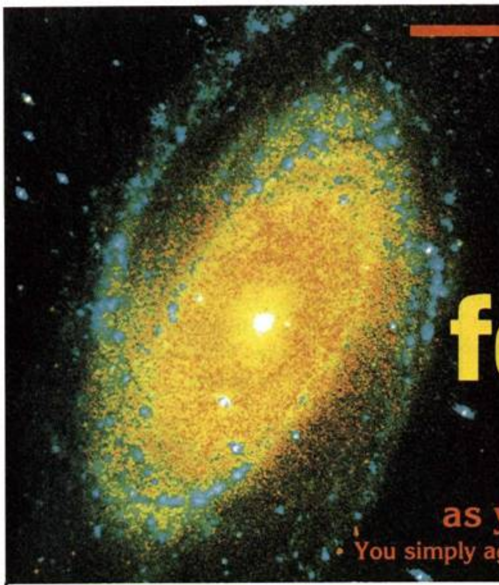
At this time, which I used to simply call sunset, I sat comfortably warm in the bubbling water and adusted the mirrors of my little plastic sextant, thinking all the while of those intrepid explorers who struggled aboard heaving ships, constantly fighting the wind, cold, and salty spray as they worked to find their way across the oceans. This funny sextant must have been badly needed, for it was invented simultaneously in England and America in 1735. I was supposed to be fiddling with the mirrors, trying to determine possible sextant error by looking at the split in the horizon (the two images were supposed to coincide). The sextant is probably just fine, I decided, and slowly, carefully, I brought the image of Sirius down to the edge of the water. "Mark!" I punched the stopwatch. Finally I found a use for the Los Angeles Olympic games souvenir I bought in 1985.

The stopwatch came in handy. When the books say time they mean the *exact* time, to the second. That includes learning how many seconds your own watch differs from station WWV, a broadcast time signal from the atomic clock in Washington, D.C. Next I turned on the flashlight and squinted to read the delicate altitude numbers etched on the sextant. After writing these things on my sight reduction chart, I waited for the next star. I already knew it would be Betelegeuse, followed by Rigel. I would do the map plotting later at the table. I hoped my star sightings would show that we were somewhere close to 33 degrees, 27 minutes West, 117 degrees, 41 minutes North — our known position.

After sighting my other stars, I looked at Sirius again and noticed how far it had moved. Holding the gray plastic instrument in my right hand, I turned the gauge with my left and again marked the time and noted the sextant altitude. I remembered that it was necessary to determine how far above sea level I sat so I could consult the *Almanac* dip chart, which computes the change in sextant altitude as we rise above the horizon. This was fairly easy, because the catamaran masts stood below me and I knew their height. Now I had two Sirius sightings. Of course, if I did both correctly I would find that in each case I was in the exact same place, in my hot tub in Laguna Beach.

But suppose the teacher were wrong. I looked back at the sky. Suppose the stars are *not* moving! Suppose for just a moment that I have moved. I could almost feel the Hot Tub drift as I watched. Suppose that I am sailing in my tiny ship Hot Tub, firmly attached to the volcanic rock of Laguna Beach, sitting on planet Earth. Then I have just moved east by several degrees. I looked at my watch, then did a little more figuring. Hmm. I reached for my calculator. That's very interesting! The way I see it I have just sailed east, we are all sailing east, at the rate of 900 knots. Now that's sailing! Finished with my homework, I sat back and sipped at the ice in the bottom of my glass, hoping to catch a meteor or two. My companion Bob, on the other hand, was still giving his sextant a lot of serious thought. I finished up my paperwork and went to bed. Bob wrote far into the night.

Some of our classmates hit the high seas before the class was finished, wanting to navigate the south Pacific before the hurricane season. We all wished them well, and they promised to send news from afar to their landlocked friends. The few remaining classes gave us a chance to view slides of wonderful cruises our teacher had photographed. Almost enough to make me want to turn my Hut Tub into a boat. The instructor wants to send Bob's paper to a navigation magazine. I rather like the serious turn our Hot Tub astronomy has taken, just as long as it doesn't get to be a habit. ☐



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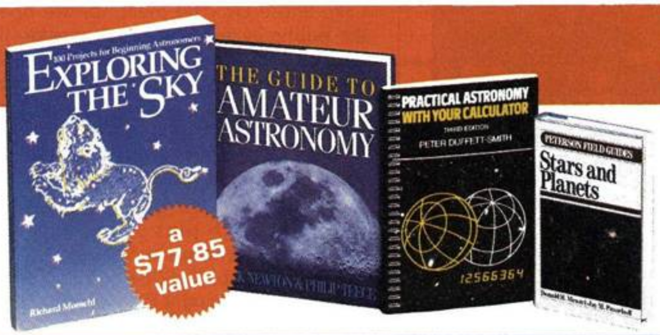

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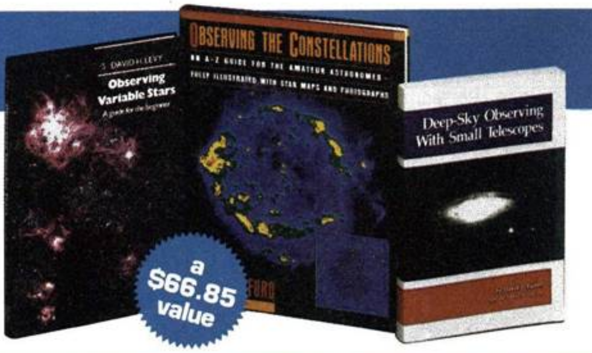

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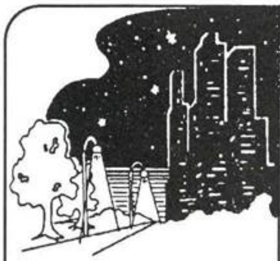

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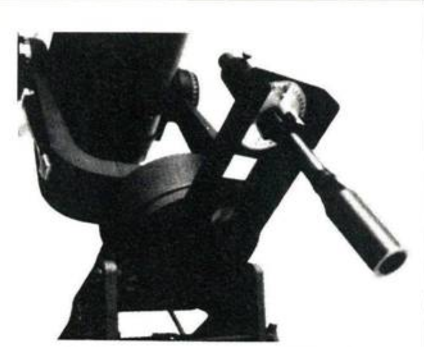

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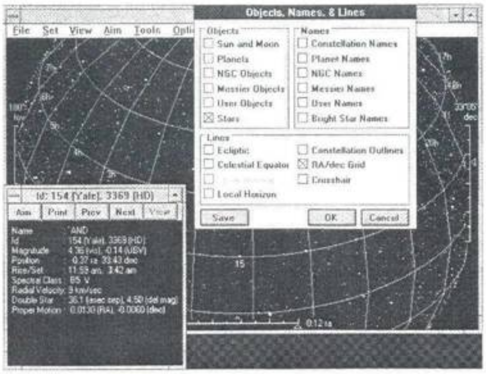

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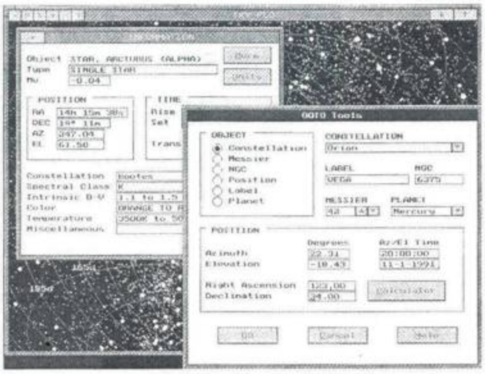
Name : AND
Id : 154 (Yale), 3369 (HD)
Magnitude : 4.36 (vis), -0.14 (UBV)
Position : 0.37 ra 33.43 dec
Rise/Set : 11.58 am, 3.42 am
Spectral Class : B5 V
Radial Velocity: 9 km/sec
Double Star : 36.1 (asec sep), 4.50 (del mag)
Proper Motion : 0.0130 (RA), -0.0060 (dec)

STARGAZE



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THE NEWEST, FARTHEST QUASAR

Three astronomers have discovered a quasar that is the most distant object now known in the universe. It is named PC 1247+3406 (PC is the catalog name and the numbers refer to the object's position in the sky). Light from the quasar has taken over 12 billion years to reach us from its position 3776 megaparsecs away. The previous record holder is 3764 megaparsecs distant. (Both distances assume that the Hubble constant has a value of 75 kilometers per second per megaparsec.)

Donald Schneider of the Institute for Advanced Study, Maarten Schmidt of Caltech, and James Gunn of Princeton reported their discovery in the September issue of the *Astronomical Journal*. The astronomers used the 5-meter Hale telescope at Palomar Observatory to measure the redshift of the quasar, which is related to the quasar's distance. PC 1247+3406 has a redshift of 4.897, while the previous record holder has a redshift of 4.733. The astronomers doubt this record is the ultimate quasar redshift because they have processed only one-seventh of their new quasar survey data.

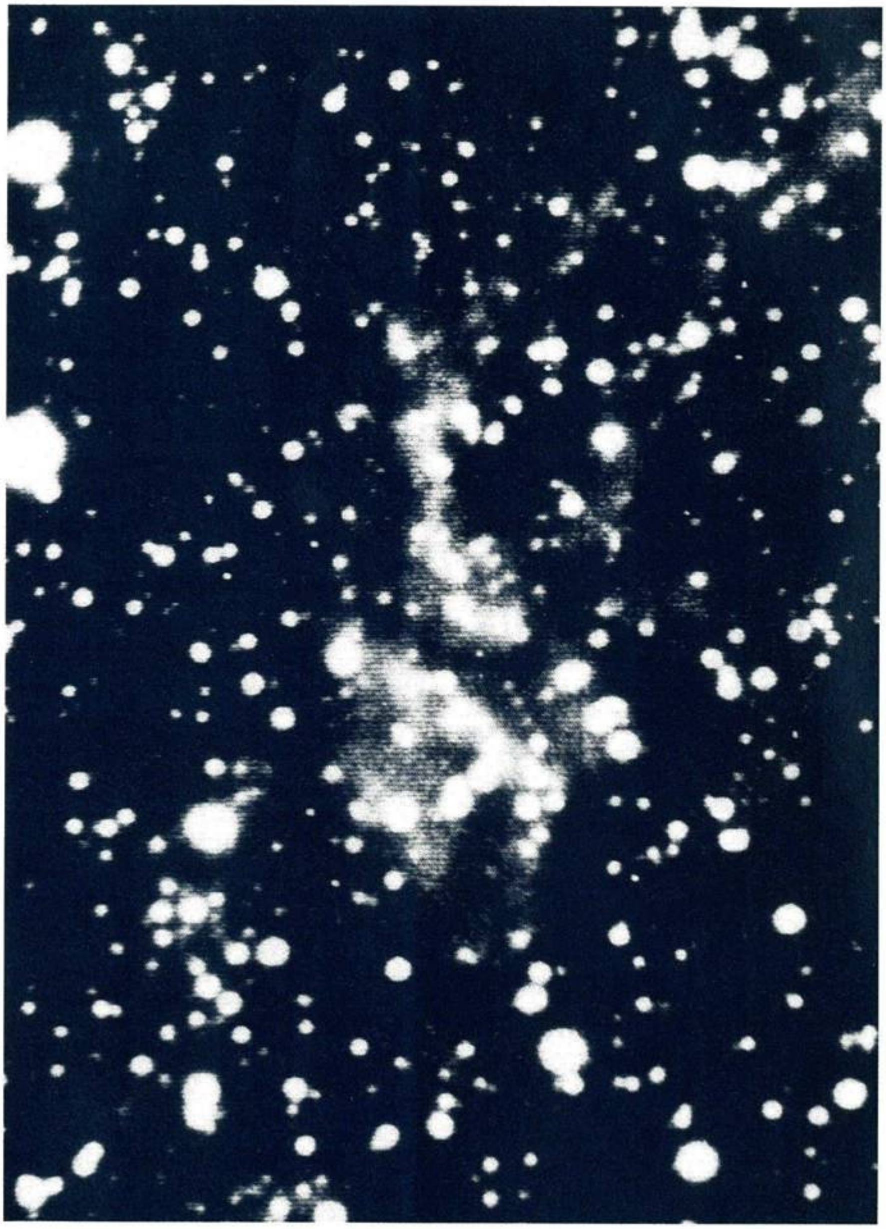
NO BLACK HOLE FOR SS 433

One of the strangest objects ever seen — a binary star system by the name of SS 433 — apparently contains a neutron star and not a black hole. The new finding surprises many astronomers, who until now had thought SS 433 was one of the better candidates for a black hole in the Galaxy.

The story of SS 433 began in 1977, when American astronomers Bruce Stephenson and Nicholas Sanduleak included the 14th-magnitude star in their list of stars with emission lines in their spectra. Other observations showed radio waves and X rays emanating from the same area. But it wasn't until astronomers took detailed spectra of the object that they knew they had found something extraordinary. These spectra showed emission lines arising from hydrogen atoms moving at up to 17 percent the speed of light, by far the highest velocity ever seen in a star in our Galaxy.

Further study led astronomers to a picture of the strange object as a binary system consisting of a hot, O- or B-type star in orbit with a smaller, compact object created in an earlier supernova explosion. A dense, rapidly spinning accretion disk of material pulled from the star surrounds the compact object. Two narrow jets of matter ejected from the compact object give rise to the observed hydrogen emission lines.

But what is the nature of the compact object — neutron star or black hole? A group of four European astronomers (Sandro D'Odorico, Tom Oosterloo, Tomaz Zwitter, and Massimo Calvani) observed the star with the European Southern Observatory's 3.5-meter New Technology Telescope to try to answer that question. By analyzing helium lines emitted by the accretion disk, they were able to determine the orbital characteristics of



FAINT NEBULOSITY surrounds the strange binary star SS 433 in this image taken with the New Technology Telescope. Recent observations indicate that the compact member of the binary system is probably a neutron star. ESO photo.

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the pair. From that and previous X-ray observations, they then deduced the masses of the stars.

Reporting in the September 26, 1991 issue of *Nature*, the researchers concluded that the compact object contained only 0.8 solar masses of material (the larger companion weighed in at 3.2 solar masses). Even given the uncertainty of the observations, this low mass rules out a black hole. The group concludes that the object is most likely a neutron star.

STARBURST IN A PRIMEVAL GALAXY

Two astronomers at the National Radio Astronomy Observatory (NRAO) have detected large amounts of carbon monoxide gas in a distant galaxy that was born when the universe was less than 20 percent its current age. Carbon monoxide is commonly found in star formation regions, so this finding makes the galaxy the oldest ever observed in the process of making stars. The finding also indicates that as early as two or three billion years after the Big Bang, galaxies were star-factories in full operation — a possibility long suggested by theory but never directly observed before.

Robert L. Brown and Paul Vanden Bout used NRAO's 12-meter radio telescope on Kitt Peak to observe the distant galaxy IRAS F10214+4724. The galaxy is a giant by any standards: it has a luminosity 300 trillion times that of the Sun and some 30,000 times that of the Milky Way. The galaxy's dust alone accounts for about as much mass as the Milky Way, and the astronomers estimate that the galaxy's carbon monoxide weighs about the same as 100 Milky Ways.

"These observations show that stars formed in the early universe just as they do today," says Brown. "But it is also clear that the first generations of stars were able to form before or while the galaxies themselves took shape."

To account for the galaxy's high luminosity (which is mostly far-infrared radiation) Brown and Vanden Bout calculate that it needs a steady population of about a billion O-type stars, which are hot, short-lived objects that would create carbon monoxide (and other elements) as they evolve. This in turn means that each year some 2,000 solar masses worth of gas is turned into new stars — and that this "starburst" activity has been going on for roughly a billion years.

Amateur News

GATHERIN' DOWN IN THE HOLLOW

In early October, amateur astronomers from 16 states converged on north-central Ohio for what has become one of the biggest astronomy meetings in the region. On the weekend of October 4 and 5 nearly 300 avid skywatchers got together for Hidden Hollow '91.

Cold Canadian air blowing across a warm Lake Erie brought partly cloudy skies to the convention site near Mansfield, Ohio, but the clouds parted enough times to allow glimpses through the Warren Rupp Observatory's 31-inch f/7 reflector.

Located at the Hidden Hollow camp, this sizable telescope is operated by the Richland Astronomical Society, the club that sponsors the Hidden Hollow meet each year. Aided by the light-gathering power of the 31-inch, at least 150 observers bagged the rarely sighted central star of the Ring Nebula. The sharp-eyed in the crowd also glimpsed IC 1296, an elusive 15th-magnitude galaxy that lies in the same field of view as the Ring.

The speakers' program got off to a good start Friday evening when astrophotographers Richard Berry, Don Parker, and Jack Newton teamed up to share their new-found experiences in the realm of CCD imaging. During the talk, Berry commented that it was an exciting time for amateur astrophotographers because for the first time, amateur color CCD images are beginning to approach the quality of conventional photography, but without the need for long exposures and hours in the darkroom. The talk proved to be so popular that Berry, Parker, and Newton repeated it again Saturday evening.

Saturday, amateurs browsed the flea market, inspected telescopes on display, and looked over the extensive display of 256 amateur astrophotographs entered into a contest sponsored by the Great Lakes Region of the Astronomical League.

On Saturday afternoon the audience was able to fire questions at an experts' panel consisting of the speakers already mentioned as well as comet finder David Levy, science writer and educator Peter Jedicke, *Sky and Telescope* associate editor Stephen James O'Meara, JPL astronomer and author Steve Edberg, and U.S. Naval Observatory astronomer Brent Archinal. The free-wheeling and lively discussion ranged from the future of amateur astronomy (which was linked to the quality of science education in the United States) to the priorities and projects of the space program.

Hidden Hollow '92 is set for September 25 and 26. If you are in the area, it is well worth attending. For more information, send a SASE to Hidden Hollow '92, P.O. Box 653, Ashland, OH 44805-0653. — *Robert Bunge*

NEW PROGRAMS UNDERWAY AT MOUNT WILSON

The Mount Wilson Institute, which operates the Mount Wilson Observatory under an agreement with the Carnegie Institution of Washington, has appointed Robert Jastrow as chairman of the Board of Trustees and director of the Mount Wilson Institute. Jastrow is the founder and former director of the NASA Goddard Institute for Space Studies. He succeeds Arthur Vaughan of the Jet Propulsion Laboratory, who continues to serve as a member of the Board of Trustees.

"We look forward to expanding the number of scientific programs and users who will take advantage of the unique qualities of the observatory site," said Jastrow. "Light pollution from the Los Angeles basin is not a hindrance for

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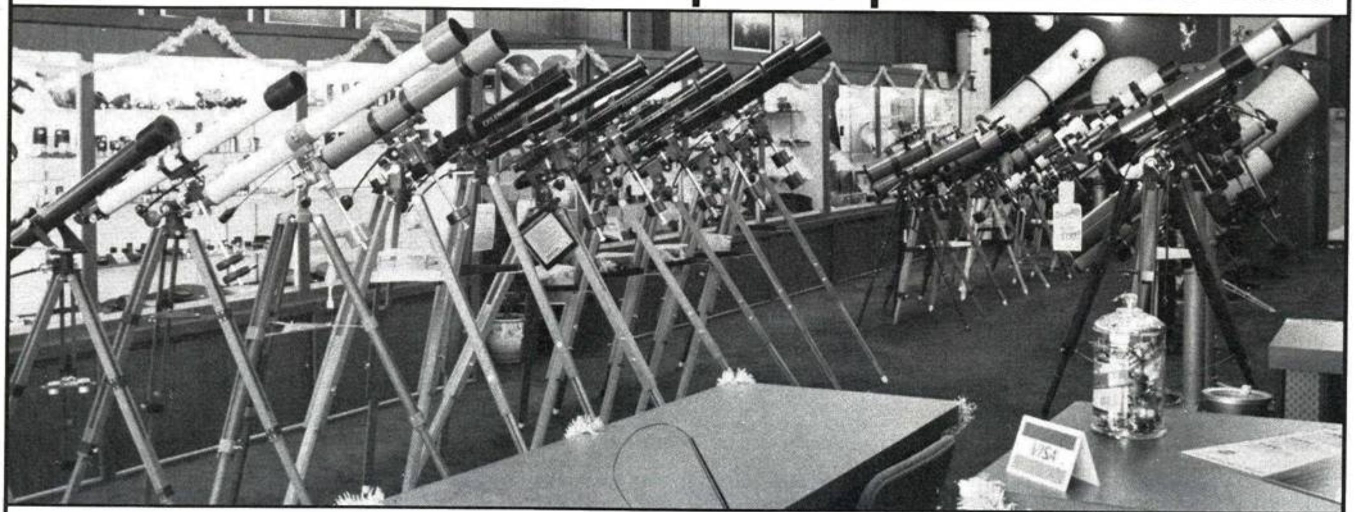

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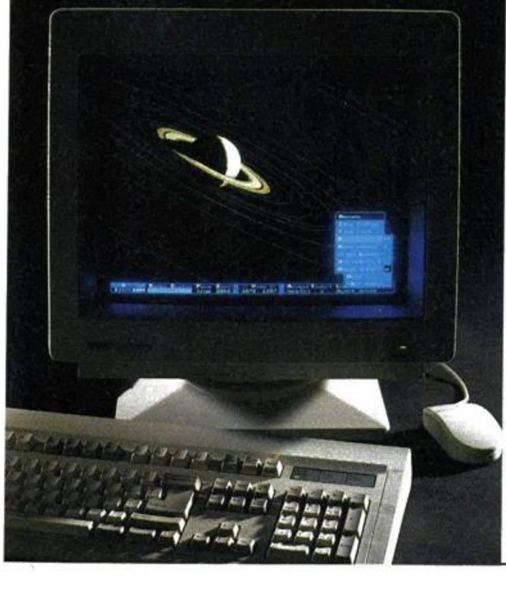

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solar, stellar and galactic studies. The Mount Wilson telescopes can contribute significantly to research in these areas."

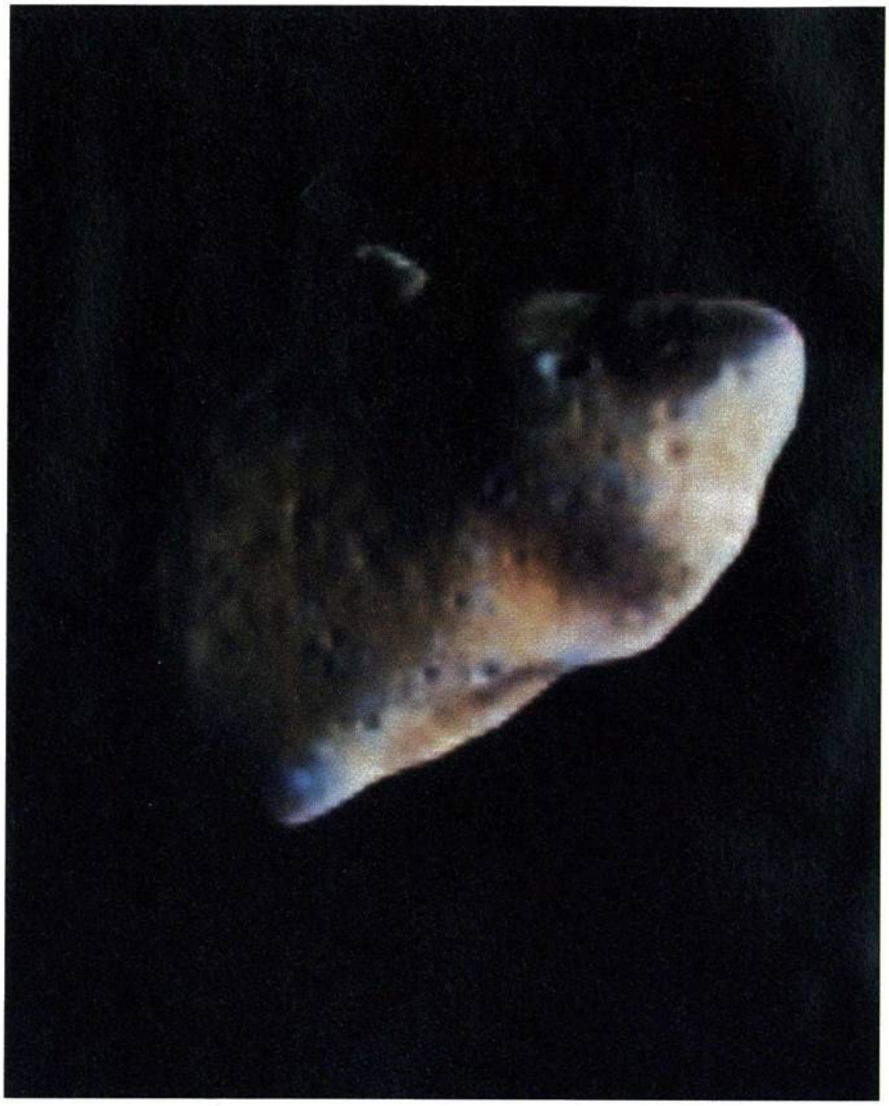
As part of this expansion of scientific programs, a new project is starting to monitor small brightness changes in solarlike stars. The collaboration of Harvard-Smithsonian Center for Astrophysics and Tennessee State University astronomers hope to obtain new information about processes in the outer layers of these stars. The detection of these changes also could have implications for the study of global warming and the Sun's influence on Earth's climate. This program joins five ongoing research programs at the observatory which include the study of stellar magnetic activity cycles, interferometry experiments, a study of the internal structure of the Sun, and continued measurements of the Sun's magnetic field. (See "Renaissance at Mount Wilson," April 1988)

The Mount Wilson Institute also appointed as deputy director Sallie Baliunas of the Harvard-Smithsonian Center for Astrophysics. Baliunas brings years of experience as principal investigator at the 60-inch telescope to her new position and shares Jastrow's desire to see new projects brought to the observatory. "Planning is underway for the installation of an adaptive optics test-bed," Baliunas said. "Studies indicate that the atmospheric seeing conditions are the best on the North American continent. These exceptional observing conditions and the availability of technological expertise in the Los Angeles area make Mount Wilson an excellent site for the test-bed experiment."

The test-bed will be installed first at the 60-inch telescope and will make use of techniques developed largely by the department of defense to reduce the effects of atmospheric blurring on telescope images. Since a typical atmospheric cell over which the light from a celestial object remains steady and not blurred is large at Mount Wilson, fewer elements are needed for the adaptive optics and the test-bed may be built inexpensively. Adaptive optics may also make it possible to observe the brightest stars in nearby galaxies from Mount Wilson in spite of the light pollution.

Jastrow added, "Once the initial development of the adaptive optics test-bed is complete, adaptive optics will be installed on the 100-inch telescope, if it is recommissioned." Engineering studies are presently being made to determine the costs involved in re-opening the telescope.

In addition to the appointments of Jastrow and Baliunas, several new members were appointed to the Board of Trustees. These distinguished scientists include Nobel Laureates Charles H. Townes of the University of California at Berkeley and Robert Wilson of the Bell Laboratories; Frederick Seitz, President Emeritus of Rockefeller University and past president of the National Academy of Sciences; and Eugene Parker of the University of Chicago. Allan Sandage of the Observatories of the Carnegie Institution of Washington serves as the Carnegie representative on the Board of Trustees.



ASTEROID GASPRA IN COLOR was captured by the Galileo spacecraft on October 29, 1991. This enhanced-color view exaggerates the subtle color variations on the surface of the asteroid, which measures 12 by 7.4 by 7 miles in extent. NASA image.

A STAR OF LESSER LIGHT

Astronomers have discovered one of the faintest stars known to exist. The red dwarf star, known by its catalog number BRI 0021–0214, has a luminosity only $^1/_{10,000}$ that of the Sun. Although only a handful of such dim stars are currently known, astronomers think there are many more and that they could contribute significantly to the total mass of the Galaxy.

The newly discovered star has a surface temperature of just 2250 kelvins and lies approximately 30 light-years away in the constellation Pisces. Because the star is so cool (for comparison, the Sun's surface temperature is

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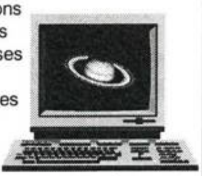

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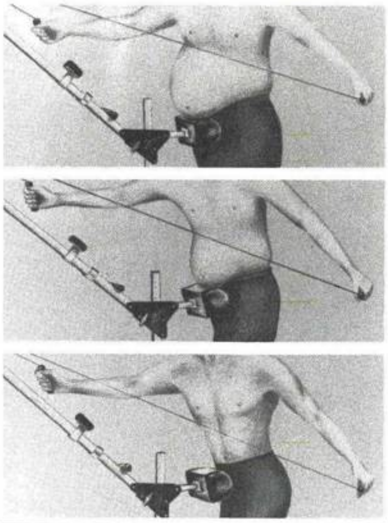

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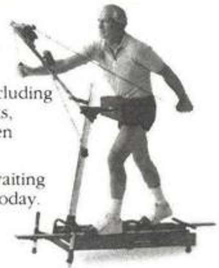

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ASTRONOMICAL LEAGUE

5800 kelvins), it emits most of its energy in the infrared. Thus it appears visually even fainter than its luminosity would suggest, shining dimly at 22nd magnitude.

Mike Irwin of the Royal Greenwich Observatory, Richard McMahon of the University of Cambridge in England, and Neill Reid of Caltech discovered the star on a sky-survey photograph taken with the United Kingdom Schmidt Telescope in Australia. Ironically, they were studying the survey photos not to find faint stars but to locate the most luminous objects in the universe — quasars. The farthest quasars appear dim because of their great distances and red because their light is highly redshifted, so they mimic the appearance of very faint, nearby stars.

Astronomers suspect that they are just seeing the tip of the faint-star iceberg. They know from studying the rotation of galaxies that much more mass is present than that contained in the visible stars, gas, and dust. A large population of faint red dwarfs and their smaller cousins, the brown dwarfs, is the simplest explanation for the discrepancy. The discovery of BRI 0021–0214 thus gives new impetus to the search for these faint objects, whose unimpressive appearance may belie their major role in galaxies.

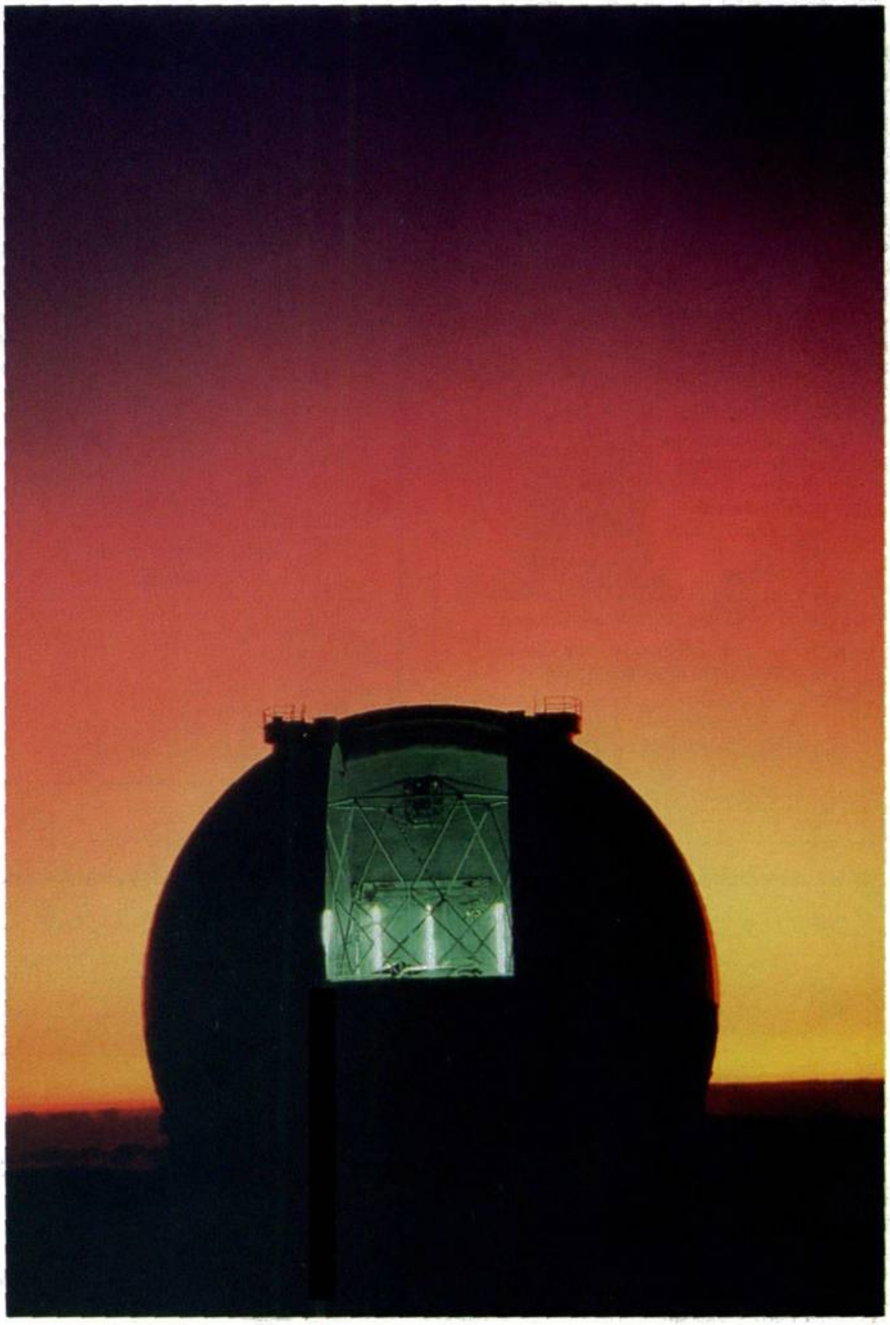
OHIO STATE WITHDRAWS FROM COLUMBUS TELESCOPE

University of Arizona officials claim the withdrawal of Ohio State University from the Columbus Telescope Project will not threaten the future of the twin 8-meter telescope project planned to be built on the summit of Mt. Graham in southern Arizona.

"We have talked to the Italians and they are willing to stick it out with us. In the meantime, we have started talking to the four other institutions that have expressed interest in becoming a partner," said University of Arizona spokesman Steve Emerine.

The Columbus Project Telescope is planned as a dual 8-meter telescope using spun-cast mirrors and was a joint project of Ohio State University, the University of Arizona, and the Arcetri Astrophysical Observatory of Florence. Italy. When plans were first proposed during the early 1980s, four partners were to split evenly the $60 million cost of the telescope and later share operating expenses. The original fourth partner, the University of Chicago, pulled out in 1988, also citing problems with fund raising.

On September 8, 1991, Ohio State President E. Gordon Gee announced that Ohio State's expected $15 million share of the project was too much for the cash-strapped university, which faced a $4 million shortfall in 1991. Even if the university had been successful at finding a single large donor for the construction costs, Ohio State officials feared they would still have problems supporting a larger astronomy department and the future costs of supporting the telescope. — *Robert Bunge*



THE WORLD'S LARGEST TELESCOPE — the W. M. Keck telescope on the summit of Mauna Kea — was officially dedicated on November 7, 1991. The Keck's 10-meter segmented mirror now has 18 of 36 segments in place, with the remainder expected to be installed by this spring. Photo by Peter French.

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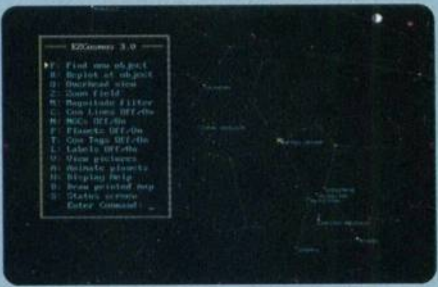

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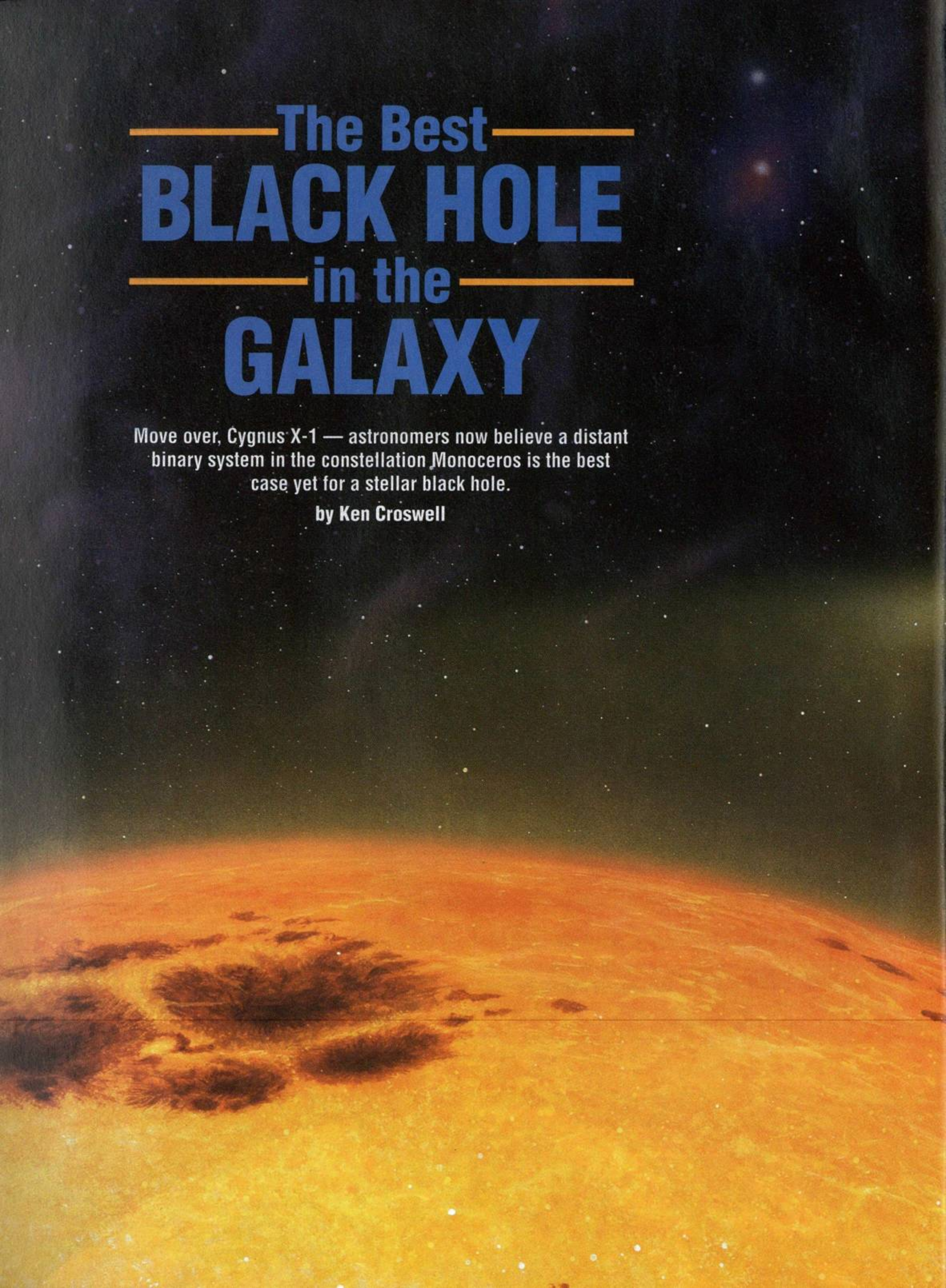
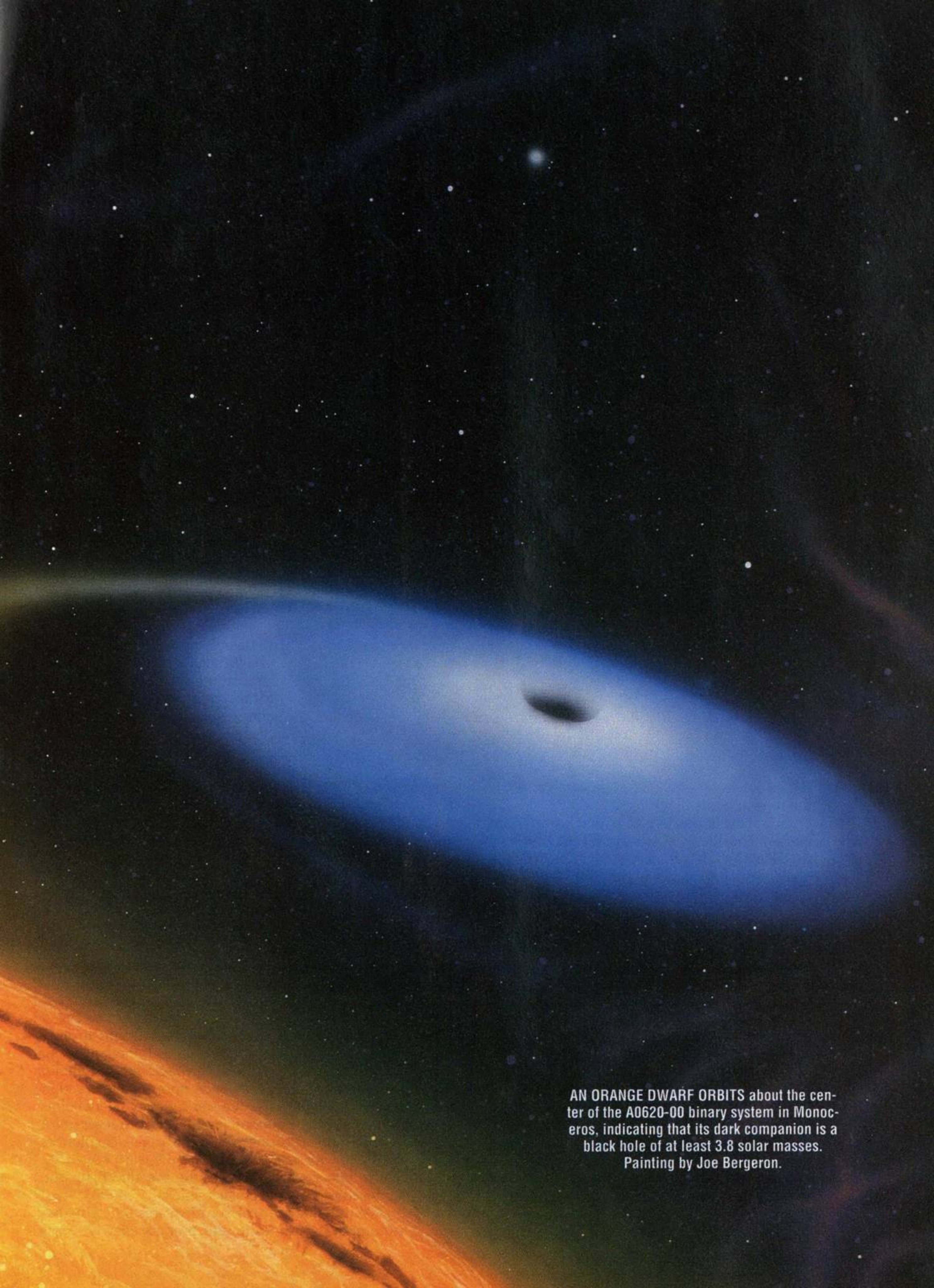
The Best BLACK HOLE in the GALAXY

Move over, Cygnus X-1 — astronomers now believe a distant binary system in the constellation Monoceros is the best case yet for a stellar black hole.

by Ken Croswell





AN ORANGE DWARF ORBITS about the center of the A0620-00 binary system in Monoceros, indicating that its dark companion is a black hole of at least 3.8 solar masses. Painting by Joe Bergeron.

On Earth, black holes are everywhere. The national debt is a black hole. The savings-and-loan mess is a black hole. A friend of mine recently claimed his graduate thesis was also a black hole. "It sucks up all my time, all my energy, all my happiness," he said. "And there's no escaping it."

In our Galaxy, however, black holes are much harder to find. For most of the last twenty years, astronomers had good evidence for only one stellar black hole in the entire Galaxy: a source of X rays in the constellation Cygnus called Cygnus X-1.

Now, though, astronomers have uncovered a much better candidate for a black hole in our Galaxy. It lies in the constellation Monoceros some three or four thousand light-years away and bears the prosaic name A0620–00. The A refers to Ariel V, the X-ray satellite that first detected the object, and the numbers refer to the object's right ascension and declination. A0620–00 was discovered in 1975, when it emitted a shower of light and X rays. Observations soon revealed that A0620–00 was a binary consisting of an orange dwarf star and a dark companion. Astronomers continue to observe the object and recent studies of the orange dwarf's motion around the dark star indicate that the dark star must be a black hole. Despite its less appealing name, A0620–00 is a better candidate for a black hole than Cygnus X-1.

Black-hole hunters look for dark objects whose mass exceeds three solar masses.

Light-Devouring Holes in Space

A black hole is an object with so much gravity that nothing can escape it — not even light, the fastest thing in the universe. Anything approaching a black hole gets pulled into the object and disappears as if it fell into a hole. Because even light cannot escape, the hole appears black.

Gravity is the key to a black hole's immense power. The black hole's strong gravity keeps captured material from escaping. Of course, every planet, moon, and star has gravity. Earth has enough gravity that you have to travel faster than 11 kilometers per second to overcome the force of gravity. This number is Earth's escape velocity. The gravity of Jupiter is even stronger: its escape velocity is 60 kms per second. A black hole has so much gravity that to escape one you would have to travel faster than the speed of light, 300,000 kms per second. But traveling faster than light is impossible, so once you get into a black hole you can't get out.

The gravitational force you feel on the surface of a planet depends on both the planet's mass and its radius. The greater the mass, the stronger the gravity and the greater the escape velocity. Less obviously, the smaller the radius, the stronger the gravity and the greater the escape velocity, too. The reason: you are then standing closer to the planet's center, so the gravitational pull on you is stronger and you have to travel faster to escape.

Anything can become a black hole if you compress it enough. For example, if Earth were the same mass it is now but had only one-fourth its present radius, the escape velocity of someone standing on its surface would be twice what it is now. If you compressed Earth still further, the escape velocity would get still higher. If Earth's diameter shrank to less than one centimeter, the escape velocity would exceed the speed of light.

Earth, of course, will never become a black hole, nor will the Sun. When the Sun runs out of fuel, it will collapse and form a white dwarf. But when a very massive star runs out of fuel, it collapses and forms a black hole.

Like the Sun, most stars support their huge weights by generating energy. This energy keeps the stars warm, and the pressure of the warm gas holds the stars up against their own gravity. Someday, though, a star exhausts its fuel. Without its energy source, the star can no longer hold itself up against the pull of its own gravity and so the star collapses. A star with an initial mass below eight solar masses collapses into a white dwarf star. White dwarfs hold themselves up not through warmth but through the pressure exerted by the star's electrons on each other.

There is a limit to how much pressure electrons can exert, however, and that limit is exceeded if the white dwarf's mass is above 1.4 solar masses. White dwarfs more massive than 1.4 solar masses therefore cannot exist. But all stars with initial masses below eight solar masses lose so much mass during their lives that they form white dwarfs with masses under 1.4 solar masses. In fact, the average mass of a white dwarf is only 0.6 solar mass.

What happens if a star is born with more than eight solar masses? After the star runs out of fuel, the outer portion explodes, forcing the core of the star to collapse. The remaining star exceeds 1.4 solar masses and so cannot form a white dwarf. Instead, as the star collapses, its electrons and protons smash together to form neutrons, and a neutron star is born. Whereas the mutual repulsion between its electrons supports a white dwarf, the mutual repulsion between neutrons supports a neutron star.

Astronomers have catalogued hundreds of neutron stars throughout the Galaxy. Some neutron stars make their presence known because they are pulsars, emitting periodic pulses of radio waves and/or X rays.

As with white dwarfs, there is a limit to how much mass a neutron star can have. If the collapsing star exceeds two or three solar masses (the exact figure is unknown, but depends upon the interaction between the neutrons), the star's gravity overwhelms the support the neutrons provide. In a fraction of a second, the star shrinks. As the star gets smaller, its surface gravity gets stronger and the escape velocity climbs higher until it exceeds the speed of light. The star has now become a black hole.

Which stars form black holes? Again, astronomers do not know the precise answer. Most stars with initial masses above eight solar masses probably form neutron stars rather than black holes, but the most massive stars of all — stars born with masses above about 40 Suns — probably form black holes.

How to Find a Black Hole

Because neutron stars with masses above three solar masses do not exist, your goal as a black-hole hunter is to find a dark object whose mass exceeds three solar masses. Then you know you have a black hole.

But finding a black hole is tough for two reasons. First, black holes obviously radiate no light. Second, the stars that eventually become black holes are quite rare. Fewer than one star in ten million has a mass exceeding 40 solar masses. Thus, black holes must be rare. Yet, of the billions of stars in our Galaxy, several thousand of them should become black holes.

Because black holes are black, a black hole isolated in space is probably impossible to discover. But if a normal star orbits the black hole, we can detect the gravitational influence of the black hole by noticing that the normal star circles an unseen companion.

Such binary systems call attention to themselves if the black hole grabs material from the normal star. The material spirals into the black hole like water going down a drain. Before this material takes the final plunge, however, it forms a disk around the black hole called an accretion disk.

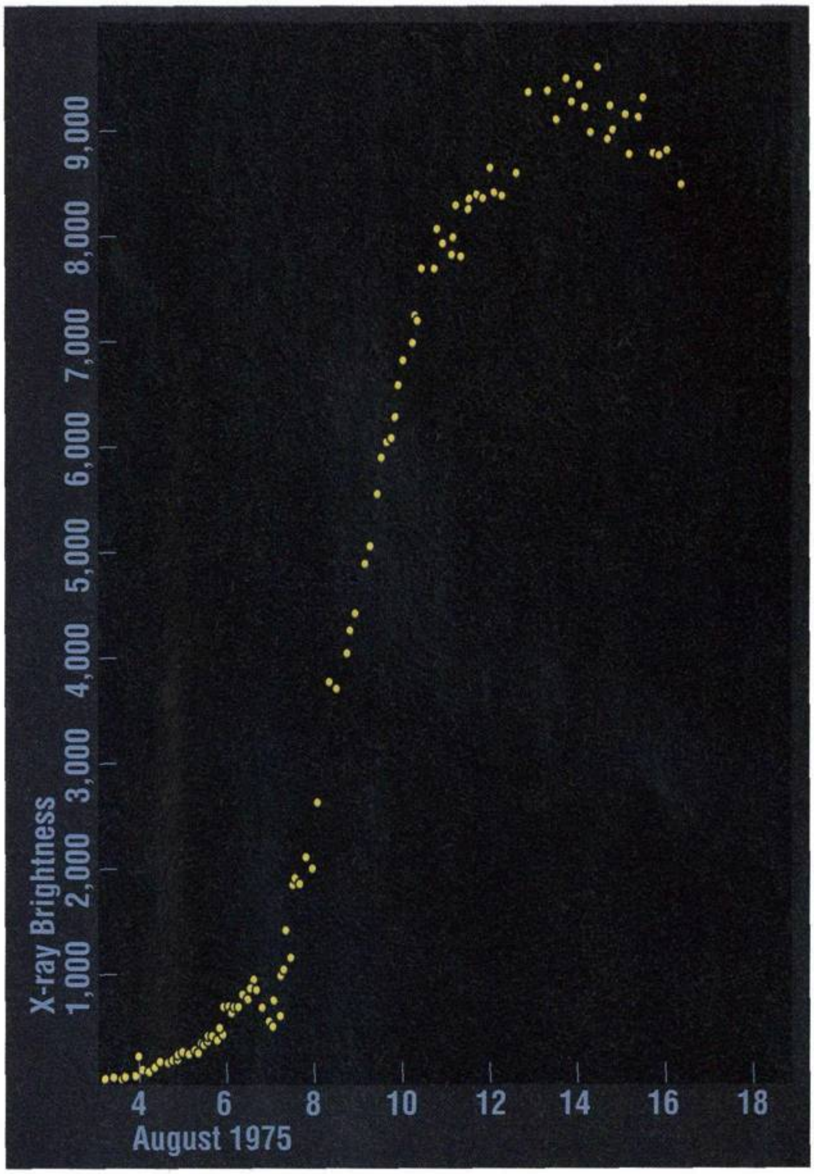
The accretion disk is extremely hot and emits X rays, which astronomers can detect. The accretion disk is hot because material is falling into it. Whenever something falls, it heats up: water falling through Hoover dam, for example, is one degree warmer at the bottom than at the top. The energy released by the falling water is converted into heat. Material falling into the accretion disk of a black hole gets heated by gravity — and by friction — and since the gravity is so strong, the temperature rises above a million degrees. Because it is so hot, the accretion disk radiates X rays. That was how Cygnus X-1 was found.

Cygnus X-1

In the 1960s, astronomers noticed X rays coming from a region in Cygnus and named the source Cygnus X-1. In 1971, they found that the X-ray source coincided with a normal 9th-magnitude star called HDE 226868. This star had been catalogued years before as a blue star of spectral type O. O-type stars have high masses and therefore are less common than the low-mass stars that make up most of our Galaxy. Still, O stars are not that unusual and several are even visible to the naked eye.

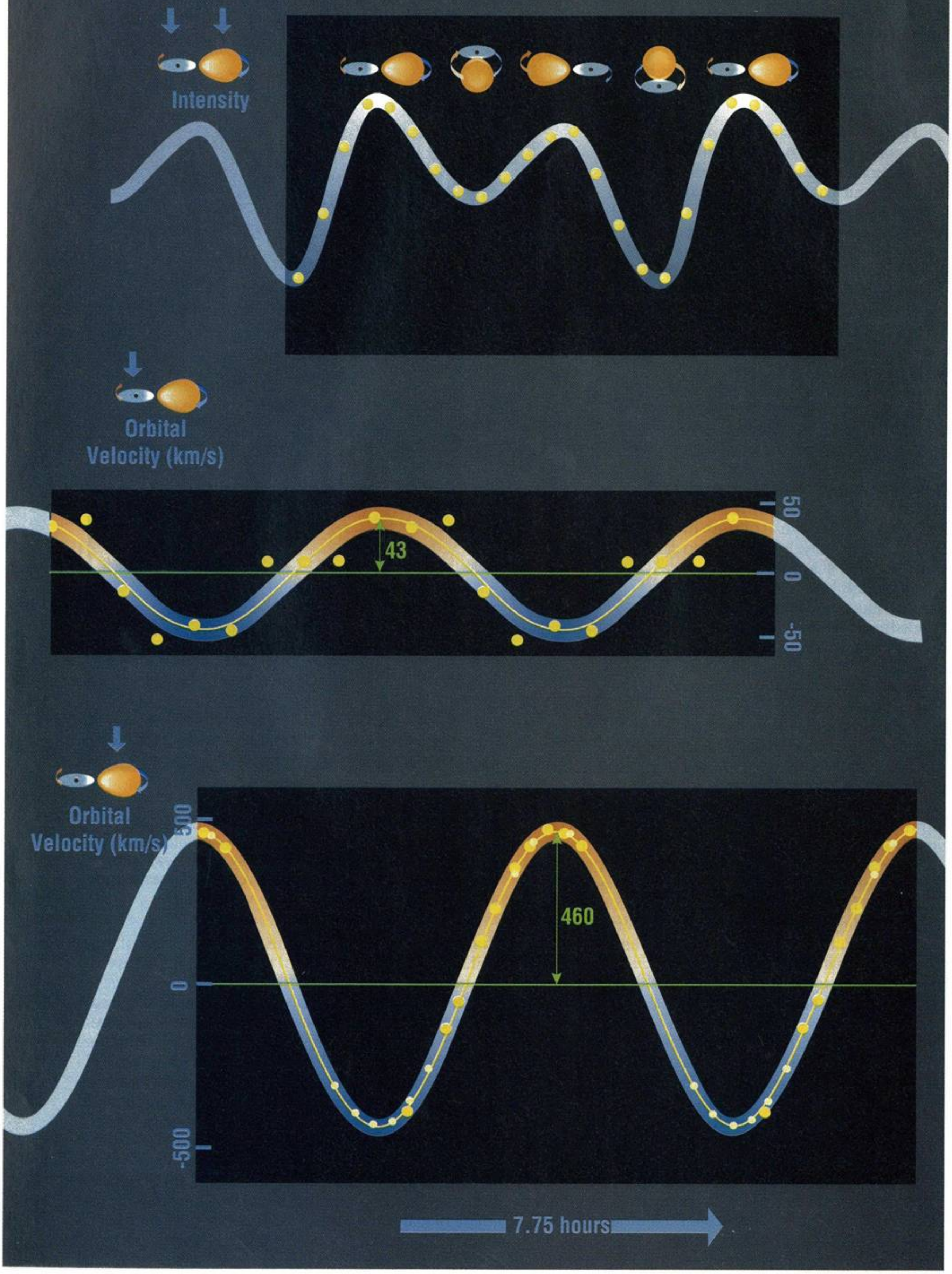
But HDE 226868 *was* unusual. Astronomers measured the star's velocity and found that the star revolved around something every 5.6 days. But the companion of HDE 226868 turned out to be dark and invisible. By assuming the O star has a high mass, as most other O stars do, astronomers concluded that in order to perturb the O star, the dark star had to exceed three solar masses. Cygnus X-1 was likely a black hole.

But it was not a definite black hole because the dynamics of the binary system say only that the dark companion must exceed 0.25 solar masses. The argument that the dark star exceeds three solar masses depends on our assuming the O star has a high mass. If the O star has less mass than usual for its spectral type



A0620–00 WAS DISCOVERED in 1975 when astronomers using the Ariel V X-ray satellite noted this X-ray outburst. An optical outburst followed the peak intensity of the X-ray transient source. Illustration from data by University of Leicester X-ray astronomy group.

How A0620-00 Works



— as do many stars in X-ray binary systems — then the unseen companion could contain less than three solar masses. In fact, some astronomers have constructed models of Cygnus X-1 in which the dark companion is only a neutron star rather than a black hole.

When dealing with exotic objects like black holes, astronomers want absolute proof. Cygnus X-1 *probably* is a black hole. But the dark star could have less than three solar masses, so Cygnus X-1 does not give us the proof we desire. Now, though, astronomers have found a perfect black hole, a dark star whose mass definitely exceeds three solar masses: A0620–00.

An X-ray Outburst in Monoceros

On August 3, 1975, the British satellite Ariel V detected a source of X rays in the constellation Monoceros, near its border with Orion. The source, A0620–00, rapidly intensified: on August 5, it surpassed the strength of the Crab Nebula; shortly after, it exceeded Cygnus X-1; and on August 8, it outdid Scorpius X-1, the strongest X-ray source in the night sky. For nearly two months, the object remained brighter than any other X-ray source except the Sun.

Then astronomers discovered an 11th-magnitude blue star at the position of A0620–00. Photographs taken at Palomar Observatory in 1955 indicated the star was normally reddish and 18th magnitude. So the X-ray outburst coincided with an optical nova, which was named V616 Monocerotis.

Searching astronomical archives, astronomers found that the nova had erupted before. In November 1917 it attained 12th magnitude, but no one had noticed it. Later examination of old sky patrol plates at Harvard University revealed the nova's outburst.

A0620-00 is now the best black-hole candidate.

The light and X rays of A0620–00 eventually faded. Today an 18th-magnitude orange star lies in this place. The star is a dwarf of spectral type K5, somewhat fainter, cooler, and smaller than the Sun. These stars are common (about 15 percent of all stars in our Galaxy) so we know a lot about them. If the orange dwarf in the A0620–00 system is a normal K5 dwarf, it has a mass around 0.7 solar mass and an intrinsic brightness five to ten percent that of the Sun. Since its apparent magnitude is 18, astronomers estimate the distance to this star to be roughly three or four thousand light-years. But A0620–00 is not a normal orange dwarf. It circles a black hole.

A Perfect Black Hole

As the X-ray outburst proved, there was more to the A0620–00 system than just an orange dwarf. After the outburst faded, observations revealed that the K star contributes only about half the total visible light the system emits. The other half comes from a hot accretion disk surrounding the orange star's unseen partner.

In 1983, Jeff McClintock of the Harvard-Smithsonian Center for Astrophysics and colleagues reported that the orange dwarf's brightness varies 0.2 magnitude every 7.75 hours, which indicates the star revolves around something every 7.75 hours. Twice during each revolution, the star's brightness, as observed on Earth, reaches a maximum; twice it reaches a minimum.

McClintock and colleagues suggested the orange dwarf varies in apparent brightness because it is not spherical. Instead, the intense gravity of the dark companion distorts the orange dwarf into an egg shape. As the orange dwarf orbits around its companion, the same side points toward the dark star. Thus, the dwarf presents different profiles to us, varying the brightness as seen from Earth (see diagram on opposite page). Twice during each revolution, we view the egg-shaped star sideways and its apparent brightness attains a maximum; twice during each revolution, we view the star end-on and its apparent brightness reaches a minimum.

What was the orange dwarf's companion? A black hole or just another neutron star? To find out, astronomers had to determine the mass of the dark star by studying the orange dwarf's orbit. If the dark star's mass exceeds three times the Sun's, the companion must be a black hole.

Unfortunately, the orbital period of the binary system as found from brightness variations does not reveal by itself the mass of the dark companion. Astronomers also need to know the separation between the dark star and the orange dwarf. For a given period, the greater the separation, the greater the mass must be. For example, if a star has a planet circling it yearly and if the planet lies one astronomical unit — the distance from the Sun to Earth — from the star, then the star must have exactly the same mass as the Sun. If, on the other hand, a planet completes an orbit once a year but lies two astronomical units from the star, the star must be eight times more massive than the Sun.

Two stars in a binary like A0620–00 actually circle their center of mass, which lies between them, instead of orbiting one another. The binary's center of mass is the place where you would put a fulcrum to balance a giant seesaw holding one star at each end. The center of mass, therefore, always lies closer to the more massive star. For example, if one star has ten times the mass of the other, the center of mass lies a tenth as far from the high-mass star as from the low-mass star. In the case of A0620–00, the center of mass lies closer to the dark star than to the orange dwarf because the dark star has more mass. Every 7.75 hours, the orange dwarf revolves about this center of mass and so does the dark star. But because the center of mass lies closer to the dark star, the dark star does not move as much as the orange dwarf does. The total separation between the dark star and the

THE BRIGHTNESS OF THE BINARY SYSTEM (top) changes as the stars orbit each other every 7.75 hours. Orbital velocities of the black hole (middle) and orange star (bottom) change between negative and positive as the two approach and recede. Dots show actual data for the system. Illustration by Steve Davis.

Battle of the Black Holes

Cygnus X-1

System data
distance = 8,200 light-years
period = 5.6 days
best estimate of masses
O9.7 supergiant — 33 solar masses
black hole — 16 solar masses

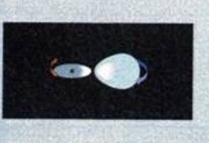
Pro

1) optical variability suggests dark star has greater than 7 solar masses
2) If O star is normal, dark star has 16 solar masses

Con

1) O star is possibly less massive than normal O stars; dark star could be a neutron star
2) distance to the binary system not well known; if closer than 5,600 light-years, dark star could be a neutron star
3) minimum possible mass for dark star — 0.25 solar mass

Large Magellanic Cloud X-3



System data
distance = 165,000 light-years
period = 1.7 days
best estimate of masses
B3 main sequence star — 6 solar masses
black hole — 9 solar masses

Pro

distance well known so brightness estimates can be used to place dark star mass at greater than 6 solar masses

Con

1) minimum possible mass suggests dark star close to neutron star limit
2) optical identification of B-star companion is not certain so orbital information is uncertain
3) brightness estimates do not include accretion disk emission, so dark star could be a neutron star

A0620-00

System data
distance=3,200 light- years
period= 0.32 day
best estimate of mass
K5 main sequence star — 0.7 solar mass
black hole — 8 solar masses

Pro

1) orbital dynamics indicate dark star must be a black hole
2) orbital parameters are well established compared to parameters of other candidates

Con

None at this time

orange dwarf — which will tell us the dark star's mass — is the same as the distance of the dark star from the center of mass plus the distance of the orange dwarf from the center of mass.

But we cannot see the separation between the two objects as we could if they were a nearby double star. Nevertheless, in 1986, McClintock and Ronald Remillard (Massachusetts Institute of Technology) put a lower limit on the separation between the dark star and the orange dwarf, which in turn puts a lower limit on the dark star's mass: 3.2 solar masses, suggestions that the dark star was indeed a black hole.

McClintock and Remillard achieved this feat by measuring the line-of-sight velocity of the orange dwarf. As the orange dwarf revolves about the center of mass, it sometimes approaches us and its light is blueshifted and, at other times, recedes from us and its light is redshifted. McClintock and Remillard measured these blueshifts and redshifts to find that the line-of-sight velocity, like the brightness, varies every 7.75 hours, confirming that the star completes an orbit every 7.75 hours. Furthermore, McClintock and Remillard found that the maximum velocity the orange dwarf attains is huge: 460 kms per second. For comparison, the Earth revolves around the Sun at only 30 kms per second.

The orange dwarf's velocity and the orbital period constrain the separation of the orange dwarf from the center of mass. If we view the binary edge-on, then the line-of-sight velocity and the period tell us how far the orange dwarf travels during a single orbit. This distance is simply the circumference of its orbit. The orbit's circumference then tells us the radius of the orbit — that is, the separation between the K star and the center of mass. The separation turns out to be 0.0136 AU. If the Sun had a planet 0.0136 AU from it, that planet would circle the Sun once every 13.9 hours. Because the period of the orange dwarf — 7.75 hours — is shorter than this, the mass of the dark star must be greater than that of the Sun. By working through the numbers, McClintock and Remillard found that the dark star had to contain at least 3.2 solar masses.

This is a lower limit because it assumes we view the binary edge-on. Chances are we don't. If, instead, the plane of the orange dwarf's orbit is tilted to our line of sight, then the true velocity of the orange dwarf (which we cannot observe) is even greater than the line-of-sight velocity (which we can observe). For example, in the extreme case when we observe a binary's orbit face on, we observe no blueshifts or redshifts at all, since neither star approaches or recedes from us.

Now, if the true orbital velocity of the orange dwarf is even greater than what McClintock and Remillard measured, the orange dwarf travels even farther in 7.75 hours, so its orbit must be larger and its separation from the center of mass greater than 0.0136 AU. This greater separation implies a greater mass for the unseen companion, because the orange dwarf now lies farther than we had previously assumed, yet it whips around the dark object so fast that it still completes an orbit every 7.75 hours.

McClintock and Remillard's figure of 3.2 solar masses is a lower limit in another sense as well. Recall that, for a given period, the mass depends on the total separation between the dark companion and the orange dwarf. McClintock and Remillard determined a lower limit only for the separation between the orange dwarf and the center of mass. In order to know the total separation between the dark companion and the orange dwarf, we must also know the distance of the unseen companion from the center of mass. The total separation between the dark companion and the orange dwarf is then the sum of the two.

> **The orbital dynamics of A0620–00 demand that it contain a black hole of at least 3.8 solar masses.**

In 1990, Carole Haswell of the University of Texas at Austin and Allen Shafter of San Diego State University further strengthened the case for a black hole in A0620–00 by determining the separation of the dark companion from the center of mass. They measured the line-of-sight velocity not only of the K dwarf but also of the dark companion itself. They find the dark companion must be at least 3.8 times more massive than the Sun.

Of course, Haswell and Shafter could not observe the black hole directly. Instead, they measured the line-of-sight velocity of the radiation coming from the black hole's accretion disk. As expected, they found that the black hole completes a revolution around the center of mass every 7.75 hours. Furthermore, the accretion disk's line-of-sight velocity is exactly out of phase with the orange dwarf's line-of-sight velocity, as it should be: When the orange dwarf approaches us, the accretion disk recedes from us; when the orange dwarf recedes from us, the accretion disk approaches.

Haswell and Shafter found that the accretion disk — and thus the black hole — attains a maximum line-of-sight velocity of 43 kms per second. Since the orange dwarf's maximum line-of-sight velocity (457 kms per second) is about 11 times greater than this, the black hole must be 11 times more massive than the orange dwarf. Furthermore, the black hole's distance from the center of mass must be $^{1}/_{11}$ the distance of the orange dwarf from the center of mass. Since the orange dwarf lies at least 0.0136 AU from the center of mass, the black hole must lie at least 0.0013 AU from the same center of mass. The total separation between the black hole and the orange dwarf is the sum of these two numbers and, therefore, is at least 0.0149 AU. Together with the period of 7.75 hours, the total separation implies that the black hole's mass is at least 3.8 times the Sun's.

As before, we get this minimum value of 3.8 solar masses by assuming that we view the binary edge-on. We probably do not view the system edge-on, in which case the true velocities are greater than the velocities we measure, and the separations of each object from the center of mass are greater as well, implying a greater mass for the black hole.

What is the most likely mass for the black hole? A normal K5 dwarf has about 0.7 solar masses. Since the black hole is nearly 11 times more massive than the orange dwarf, the black hole probably has a mass around seven or eight times the Sun's. This estimate depends on our assuming that the K star is a normal orange dwarf and so could be wrong. Though a well-understood type of star, normal orange dwarfs do not circle black holes, nor are they shaped like eggs the way the K star in A0620–00 is.

Nevertheless, from the dynamics of the binary system alone, astronomers conclude that the dark object has at least 3.8 solar masses. It is too massive to be a neutron star. It must therefore be a black hole.

Despite its more poetic name, Cygnus X-1 cannot make such a claim. In fact, from the orbital motion of the O-type star in Cygnus X-1, all astronomers can say is that the dark companion must have a mass of at least 0.25 solar masses — not much of a constraint. Evidence that the dark star has a large mass comes from other arguments less secure than orbital dynamics. Thus, although the dark star in Cygnus X-1 is probably a black hole, the dynamics of the binary itself do not force us to conclude that it must be.

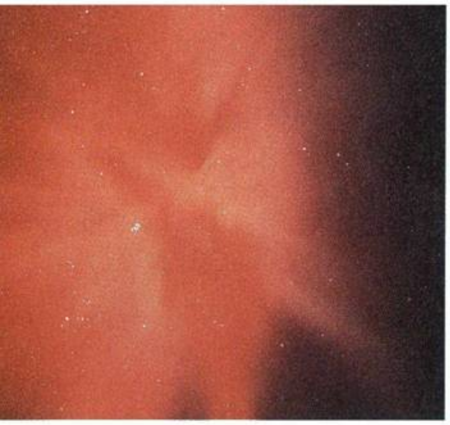
In contrast, the dark star in A0620–00 must exceed three solar masses and must be a black hole. We know this from the best method possible: the dynamics of the binary that contains the dark star. For no other system in the Galaxy is the evidence so strong and the argument so compelling. A0620–00 is by far the best black hole in the entire Galaxy — and the firmest evidence astronomers yet have that these exotic and extreme stars really exist. □

Ken Croswell received his doctorate in astronomy from Harvard University and has written for New Scientist, Star Date, *and many other publications. His last article for ASTRONOMY was "Encounter in Orion" in the January 1992 issue.*

FIRE IN THE SKY

Glowing curtains, softly pulsing streamers — the spellbinding light of an aurora forges an eerie link between the Sun and our planet's atmosphere.

by Russ Sampson



When the northern lights come out, it looks as if the sky is on fire. These dancing patterns of light and color provide an impressive show in the nighttime sky, one that everyone in the United States and Canada has had a chance to see in the last few years. In particular, on several occasions since 1989 the northern lights, or aurora borealis, have reached down to tropical latitudes to provide memorable displays that could be seen over much of the North American continent. In 1991 alone, there were far-reaching displays in March, June, and November that ranked amongst the finest ever seen.

If you've been lucky enough to witness one of these displays, you probably wondered about their origin. What causes the northern lights and what creates the colors and the motion? Though the phenomenon has been observed and recorded for thousands of years, only in the past few decades has the source of the northern lights been discovered.

Magnetic Attraction

Since the mid-1800s researchers have suspected that the cause of aurorae was somehow related to solar activity and Earth's magnetic field. But it wasn't until the space age that the full extent of our planet's magnetic field and its connection to the Sun became clear.

Just like bar magnets we used in grade school science class, Earth's magnetic field is dipolar — it has a north and a south pole. Earth's north magnetic pole is located in the Canadian arctic archipelago while the south pole is just off the coast of Antarctica toward Australia. (Aurorae in the Northern Hemisphere are called aurora borealis; in the Southern Hemisphere, aurora australis.)

The magnetic field of Earth is generated deep within the planet's core and extends far into space. Mapping the boundaries of the field wasn't possible until the launch of the first artificial satellites in the late 1950s. To their surprise, scientists found that the field is not round and symmetrical but is greatly elongated. The picture that quickly emerged from the early satellite data was one of an ever-present stream of particles from the Sun sculpting Earth's magnetic field into a comet-like shape. Just like a comet's tail of gas, Earth's tail of magnetic fields (or "magnetotail") always points away from the Sun.

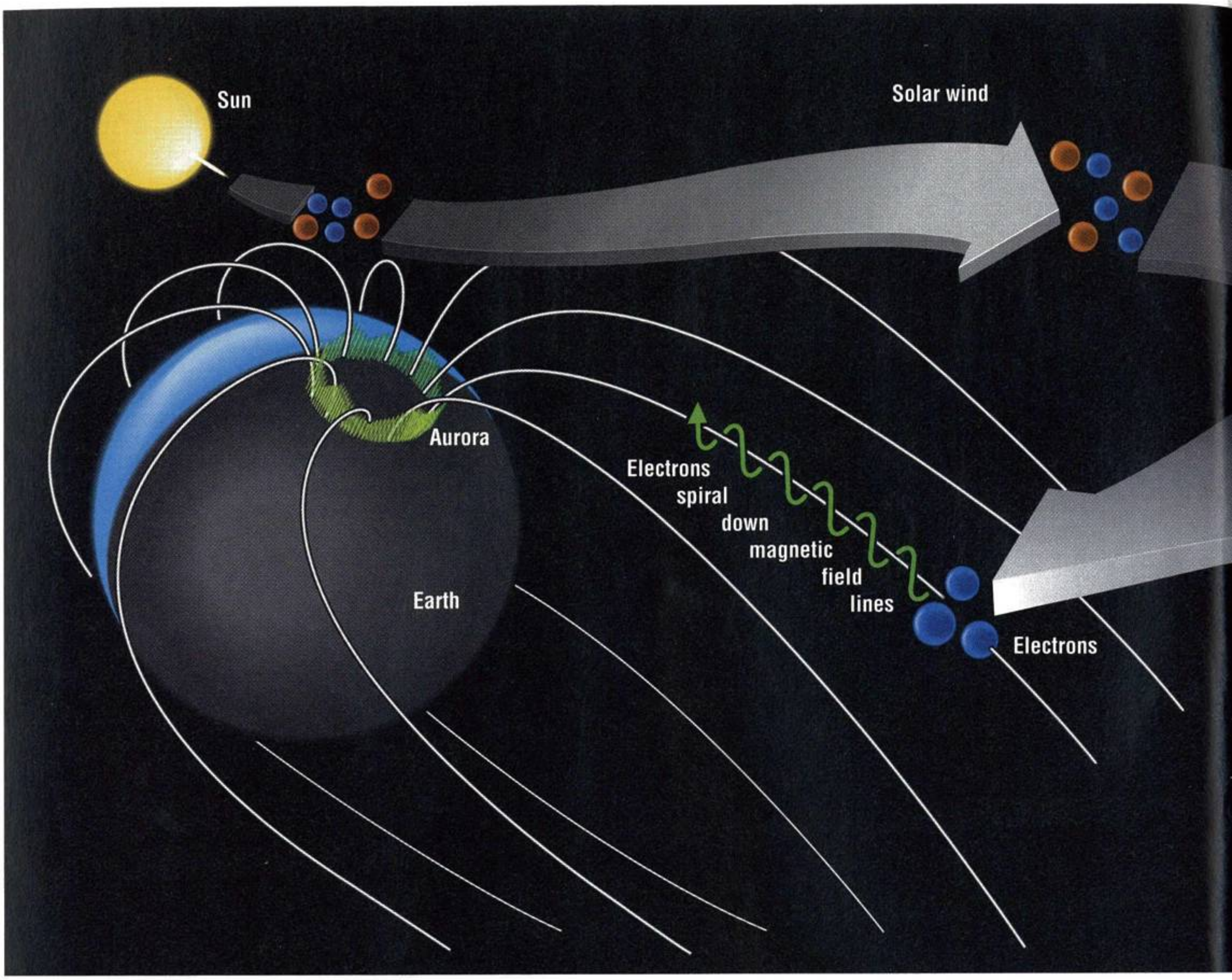
The stream of charged particles from the Sun, or solar wind, consists mostly of electrons and protons. Aurorae are produced when these charged particles collide with Earth's atmosphere. That's the simple explanation. For a more detailed picture, let's follow an electron and a proton on their journey from the Sun.

A Particle-Sorting Machine

The Sun constantly sprays the solar system with millions of tons of charged particles each minute. Particularly energetic surface events such as solar flares greatly increase the number and energy of the charged particles shot out from the Sun.

Like Earth, the Sun also has a magnetic field, although in its case, the field fills the entire solar system. Scientists call this the interplanetary magnetic field. The protons and electrons ejected by flares are propelled away from the

THE BRIGHT RED AURORA of November 8, 1991, was captured by Terence Dickinson (far left and top). Russ Sampson recorded a rare blue-violet display on June 5, 1991 (middle), and a typical green display on September 4, 1989 (bottom). The photos near left were taken looking straight overhead.



THEY COME FROM FLARES on the Sun but when they reach Earth, Earth's magnetic field separates the solar protons from the solar electrons. The free electrons spiral down the magnetic field lines and collide with our atmosphere, creating aurorae. Illustration by Steve Davis based on art by Russ Sampson.

Sun and follow these interplanetary field lines. Inevitably, a small percentage of the particles encounter Earth's magnetic field. Since the electron carries a negative electrical charge and the proton a positive charge, the two particles behave differently when they encounter Earth's magnetic domain, or "magnetosphere." Like an enormous sorting machine, the magnetic field separates the protons from the electrons as they pass into the magnetosphere.

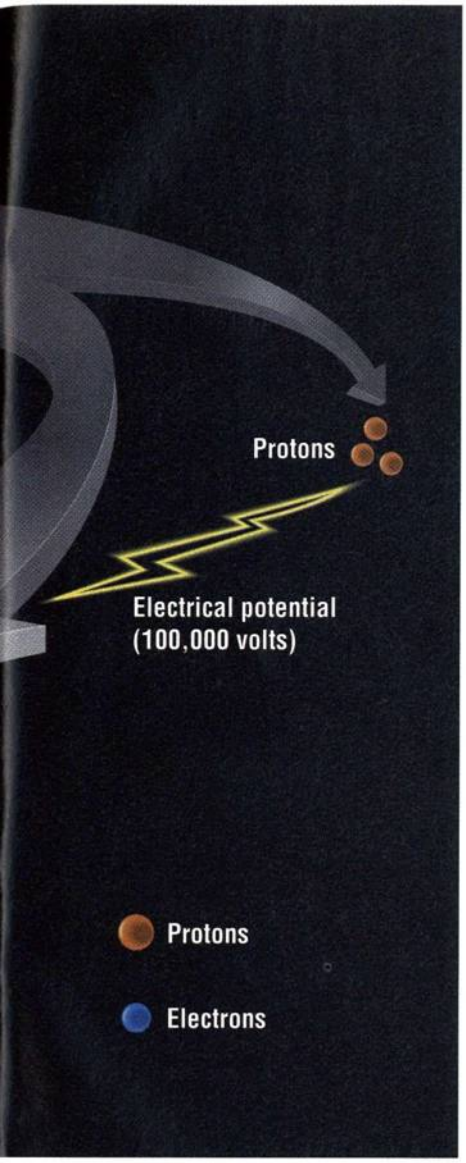
Forcing the electrons and protons apart in this manner creates an electric potential. It's just like pulling laundry apart after taking it out of the dryer. In this case, your fluffy sweater acquires a positive charge (an excess of protons) while the old sock acquires a negative charge (an excess of electrons). The difference in charge between the two bits of clothing creates an electric potential which can be demonstrated when you bring the two close together. The two pieces are attracted to each other, the infamous "static cling." As the two meet, a current of electricity (free-flowing electrons) passes from one to the other.

In Earth's magnetosphere the separation of the protons and electrons creates an electric potential of between 20,000 and 150,000 volts. This turns the magnetosphere into an enormous battery, storing the electric energy it has received from the solar wind. Some current is always flowing along Earth's magnetic field lines, but on some occasions the stored energy is released in a burst. When the magnetic field lines channel the energy into the atmosphere, we get aurorae. The question is, What triggers the release of the stored potential? The answer is currently a topic of energetic debate.

Planetary Television

Until recently the most popular trigger model had the magnetotail stretched out by the force of the solar wind and the magnetic field of the Sun. According to the theory, the end of the outstretched magnetotail can snap off and then reconnect. This results in an electrical imbalance that can send jets of particles down into the upper atmosphere.

A competing idea uses turbulent



waves in the outer edges of the magnetotail to inject charged particles down toward Earth. According to aurora researcher Gordon Rostoker of the University of Alberta, some of these waves may be produced by the solar wind's blowing over the boundary of the magnetotail like wind making waves on a lake. Increased solar activity makes these waves more frequent and more energetic.

Though their trigger mechanisms vary, both theories agree that energized electrons spiral down the magnetic field lines toward Earth. (The proton's fate is less certain — it appears that while some protons do bombard the atmosphere, they are not energetic enough to cause intense aurorae.) Some of these field lines converge near the polar regions to form a rough oval centered around the two magnetic poles. The collision of electrons with the atmosphere therefore occurs around this large oval and, when the process is active, forms a glowing ring of light that has been photographed by high-altitude satellites.

The process can be likened to the process in a television picture tube: in a TV tube magnetic fields focus a beam of electrons onto the front screen, creating patterns of light on the screen. With our "auroral picture tube," the atmosphere acts like a planet-wide TV screen being painted by electron beams streaming down from a source in the magnetosphere.

The actual auroral glows are created when the incoming charged particles hit the level of the atmosphere called the ionosphere at an altitude of between 100 and 400 kilometers. However, the characteristic folded-curtain shapes are thought to have their origin in the motions of chaotic magnetic and electrical fields in a region between 10,000 and 20,000 kilometers above the surface of Earth.

Quantum Rainbows

Though the shapes of an aurora can be traced back into space, the light and colors originate in the atmosphere. When a high-energy solar particle collides with an atom of atmospheric gas it transfers a portion of its energy to the gas atom. The target atom becomes energized and unstable. The laws of atomic physics state that an atom can attain only certain energy levels and nothing in between.

Each type of atom (for example, of oxygen) can exist at any one of several discrete energy levels that are unique to that element. But a pumped-up atom quickly gives up its energy. When an atom drops from a high energy level to a lower one, it emits a characteristic wavelength of light, a burst of color unique to that element.

The most common auroral color, green, is caused by atomic oxygen glowing at a wavelength of 558 nanometers (nm). If you see deep reds over large parts of the sky, you are seeing light coming from rarefied oxygen at the upper reaches of the aurora-forming zone, an altitude of 200 to 400 km. These great red aurorae occur only when the incoming particles are extremely energetic. The high energy combines with the low density of gas at high altitudes to spark otherwise rare oxygen emissions at 630 and 636 nm. High energy and high altitude are also the ingredients needed to enable lower latitude observers to see aurorae. On the rare occasions they do, it is often a red aurora.

The bottom edge of the most brilliant green curtains are sometimes tinged with a fringe of pink. This is produced at an altitude of just under 100 kilometers by molecular nitrogen glowing at a number of wavelengths between 650 and 680 nm. Rare blues and violets are produced by nitrogen molecules glowing between 391 and 470 nm. The yellows and other pastel colors are mixtures of the primary hues of red, green, and blue and are not caused by actual emission lines.

Sparking an Aurora

There is still much to learn about the aurora and the relationship between the magnetic field of the Sun and Earth. Recent satellites such as CRRES (NASA and the Department of Defense's Combined Release and Radiation Effects Satellite) have attempted to do just that. On several nights in early 1991, CRRES released explosions of chemicals into the magnetosphere. Once in space, the chemicals' atoms split apart, or ionized, into electrons and protons by solar radiation. These artificially introduced particles then followed the same magnetic pathways as the electrons and protons that produce aurorae. The expanding cloud of gas also pushed apart the magnetic field lines, creating a hole in the field called a magnetic cavity. It is just such an instability in the magnetosphere that may cause a cascade of particles down the field lines, triggering an aurora.

Artificially inducing an aurora was one of the goals of CRRES. According to Jeffrey Hughes, director of the Center for Space Physics at Boston University, two of CRRES's high altitude barium releases (between 13,000 and 32,000 km) were intended to trigger an auroral event. Although the results are inconclusive, it appears that both chemical detonations were followed almost immediately by auroral activity.

The purpose of these experiments is more than just scientific curiosity — aurorae and their related geomagnetic phenomena have very marked effects on our technological society. During the great auroral display of March 13, 1989, almost the entire province of Quebec was plunged into darkness. The widespread power failure was caused by an electrical current induced into the Quebec power grid.

PHOTOGRAPHING AN AURORA

Capturing an aurora on film requires the simplest of equipment. All you need is a camera that has a bulb setting (look for a T or a B on the shutter speed dial), a tripod, a cable release, and some fast film.

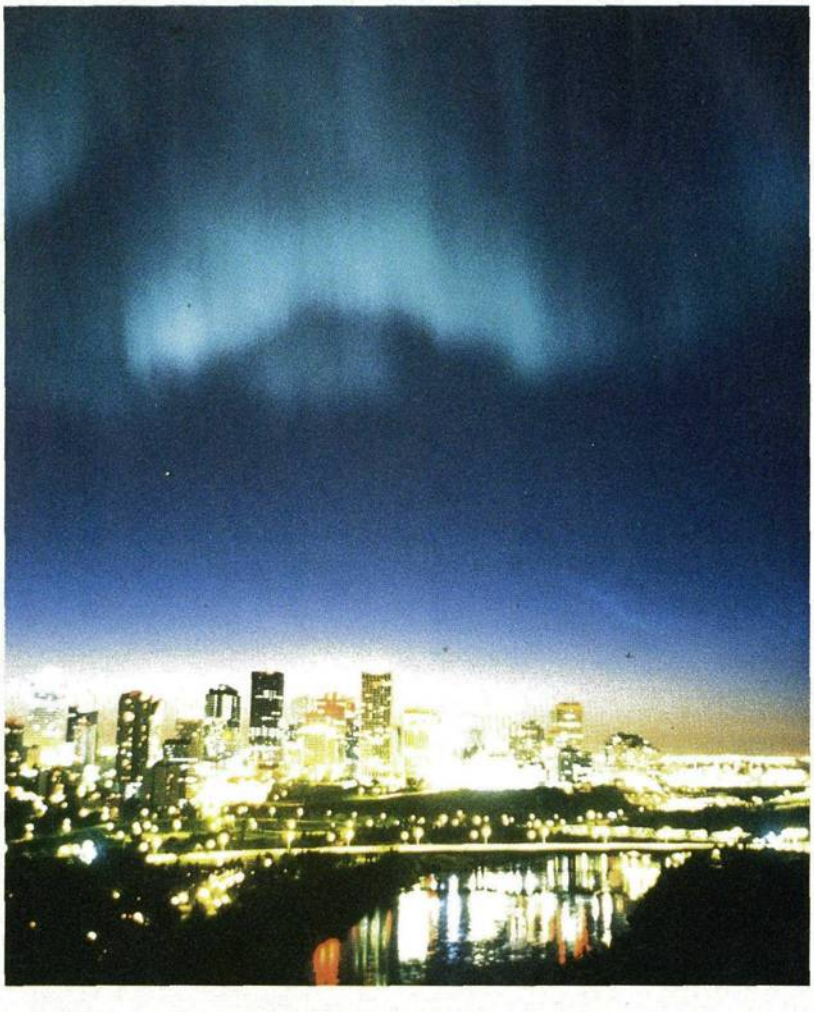
Use the widest and fastest lens you own. A 50mm normal lens (assuming you have a 35mm format camera) will do, but a 28mm or 20mm lens is much better for capturing the sweeping arc of a bright display or those rare converging curtains at the zenith.

My favorite film is Fujichrome 1600D processed at ISO 800, but any ISO 400 to 800 film will give good results.

Your exposures will depend on the brightness of the aurora. For faint displays, which can sometimes show beautiful hidden colors, I keep the shutter open for about 30 seconds with the aperture set between f/2 and f/2.8 using ISO 800 film. Brilliant aurorae can be photographed in 2 to 5 seconds with the same aperture and film.

For the most striking photos, include a familiar horizon such as silhouetted trees, distant houses or, in the case of a very bright aurora, a cityscape. Be careful not to have unwanted telephone wires and power poles in your image. A nice touch is to include a recognizable constellation in the frame.

Be prepared to shoot a great deal of film — an aurora changes quickly and you never know when the next one will appear.



INCLUDING A FAMILIAR LANDSCAPE makes for a remarkable aurora photo. On June 6, 1991, the author captured a very blue aurora over the skyline of Edmonton using a 35mm lens at f/2.8 and a 2-second exposure on Fujichrome 1600D film developed at ISO 800.

The excess electricity came from the same geomagnetic storm that was producing one of the best auroral light shows of this century.

Catching an Aurora in the Act

Practical applications aside, observing an aurora is rewarding simply for the sheer beauty of the display. A brilliant show of northern lights is a must-see event, ranking with a total solar eclipse or a daylight comet for visual thrill.

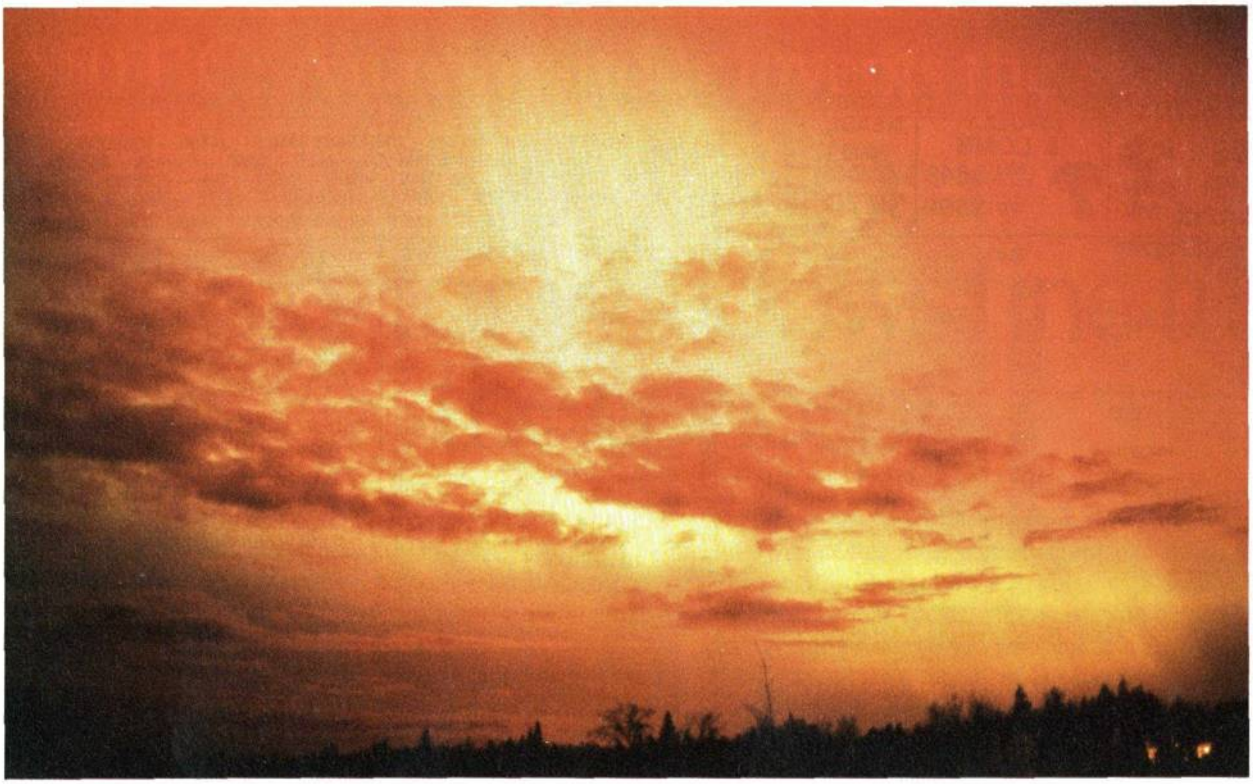
Auroral displays are not rare on Earth — they occur almost every night. What makes them difficult to observe is *where* they happen. In North America the auroral oval falls over Labrador, northern Quebec and northern Manitoba, the Northwest Territories, Yukon, and Alaska. Residents of these areas can see at least a faint auroral display every clear, dark night. Of course, during the summer months far northern locations experience little or no darkness, so aurorae, though present in the daytime sky, can't be seen. As you travel south of the main auroral oval the displays become less frequent.

When the Sun is as active as it has been the last three years, the width of the auroral oval expands and moves south. From my home in Edmonton, Alberta, the aurora appears about once every four or five nights. From the northern United States, you can expect an aurora to appear about once every two to five weeks. Those living in the southern United States may see it only once or twice a year. Points farther south are less fortunate, having an aurora grace their skies perhaps once in a lifetime.

No matter where you live, you maximize your chances of seeing an aurora by keeping an eye on solar activity. Astronomers have long known that the frequency of aurorae follows the 11-year sunspot cycle. As the number of sunspots increases so do the number and intensity of aurorae.

The Sun's activity peaked in 1989, then subsided in 1990. Then the Sun resurged in 1991 with record-breaking flare activity in March and June. With the Sun still running at a high level of activity, anything can happen and 1992 may well bring more super-aurorae.

One method of monitoring solar activity and the prospects for an au-



WHEN YOU SEE RED over a broad stretch of sky, you are seeing auroral light coming from several hundred kilometers up. To record the November 8 display, Terence Dickinson used a 24mm f/2.8 lens and a 15-second exposure on Fujichrome 400 film.

rora is with a short-wave or "world band" radio. Tune in radio station WWV, broadcast from Fort Collins, Colorado, or WWVH from Kauai, Hawaii. (They can be heard on frequencies of 2.5, 5.0, 10.0, 15.0, and 20.0 megahertz.) These stations broadcast continuous time signals but at exactly 18 minutes after each hour on WWV, and 45 minutes after the hour on WWVH, they present a brief geophysical alert. The broadcasts provide numbers for such things as the solar flux but the most telling information for aurora watchers is the description of the geomagnetic field.

A field described as "quiet or unsettled" usually means aurorae will be visible only from northern Canada and Alaska. An "active" geomagnetic field may produce displays visible from central to southern Canada. If a "minor geomagnetic storm" is predicted or in progress then residents in the northern United States may be in luck. The most widespread displays will come from what are labeled "major or severe geomagnetic storms."

The WWV reports are handy, but there is a slight problem: short wave radio reception is severely affected by geomagnetic storms. When you really need to hear WWV it may be wiped out! As an alternative, you can hear a recording of the current hour's geophysical alert by dialing (303) 497-3235. Interested observers can also join the aurora alert hotline run by David Huestis, 25 Manley Dr., Pascoag, RI 02859, (401) 568-9370.

Though aurorae can appear at any time of the year, statistics show that aurorae occur most frequently around the vernal and autumnal equinoxes. The reason for this is still poorly understood. It may be caused by a more favorable orientation of Earth's magnetic field with respect to the Sun's field. During March and September the two magnetic fields can perhaps more easily connect, providing a better conduit for the transfer of energy from the solar wind to the magnetosphere.

The best time of the night to see aurorae appears to be around local midnight. However, on rare occasions such as November 8, 1991, bright displays have appeared as early as 6 or 7 p.m. They can also peak as late as 7 in the morning.

Typically, a display starts in the late evening as a faint band or arc of light in the northern sky. At this stage it's easy to mistake it for clouds or lights from a distant town. If it is a strong display, the aurora will move south as it grows in intensity.

An aurora can be in the sky all night but the brightest and most dynamic part of the display often lasts only a few minutes. This is when the sky can be filled with multicolored rays and curtains. Great displays will move overhead and form what looks like a tunnel of light. You are in fact looking up the vertical curtains of the aurora, several hundred kilometers tall — a perspective that makes the curtains appear to converge near the zenith.

The more active displays usually end with a leftover patchwork of faint pulsating light that persists for the rest of the night. On a few occasions, however, I witnessed two bright waves of aurorae in the same night. Since it is difficult to predict when the best part of the display will occur, ardent aurora watchers need to check the sky every few minutes.

Though it may take patience, eventually your aurora watches will be rewarded. Once feared as evil omens by cultures around the world, aurorae are now a target of scientific curiosity. But all we know about the northern lights hasn't diminished their beauty. Standing under an aurora reminds us of the power of nature and the remarkable connection between Earth and sky. With luck, in the next few months you'll have an opportunity to experience that power and marvel at that connection. ☐

Russ Sampson is a freelance science writer and broadcaster as well as an avid amateur astronomer living in Edmonton, Alberta, Canada.

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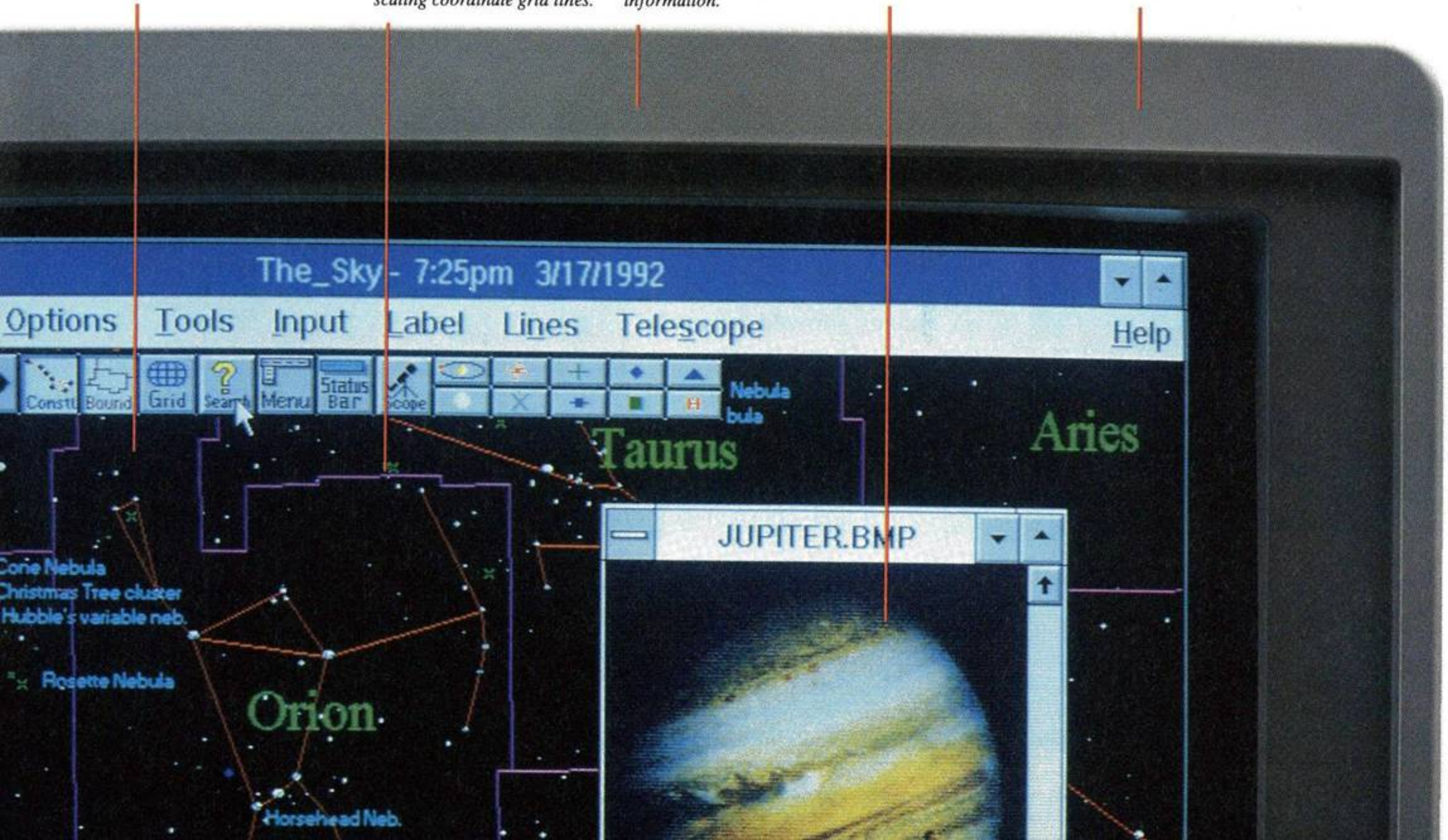
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STAR DUST

Wispy clouds of cosmic dust permeate the space between the stars.

by Gerrit L. Verschuur

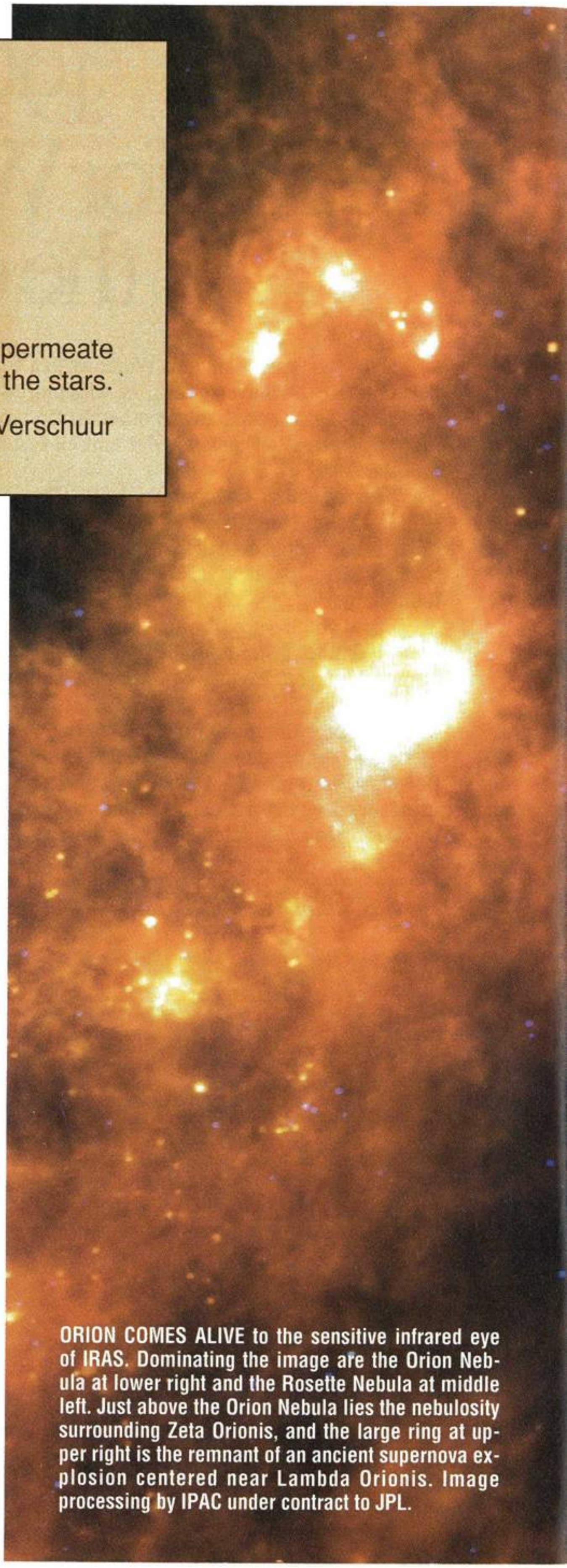
Astronomers have long sought to understand the dark clouds that loom among the stars in the Milky Way. For more than half a century, they have known that stars are born from interstellar matter. But they still do not know what happens in the earliest stages of star formation, before matter coalesces into the blobs that give birth to stars. By studying the dark clouds in the Milky Way and learning their most intimate secrets, astronomers hope to shed light on this fascinating chain of events.

The launch of the Infrared Astronomical Satellite (IRAS) in 1983 set the stage. The satellite provided the first clear and comprehensive view of the infrared universe from above Earth's atmosphere, which blocks most infrared radiation. Astronomers from around the world have been milking the IRAS database ever since to learn as much as they can about the interstellar medium.

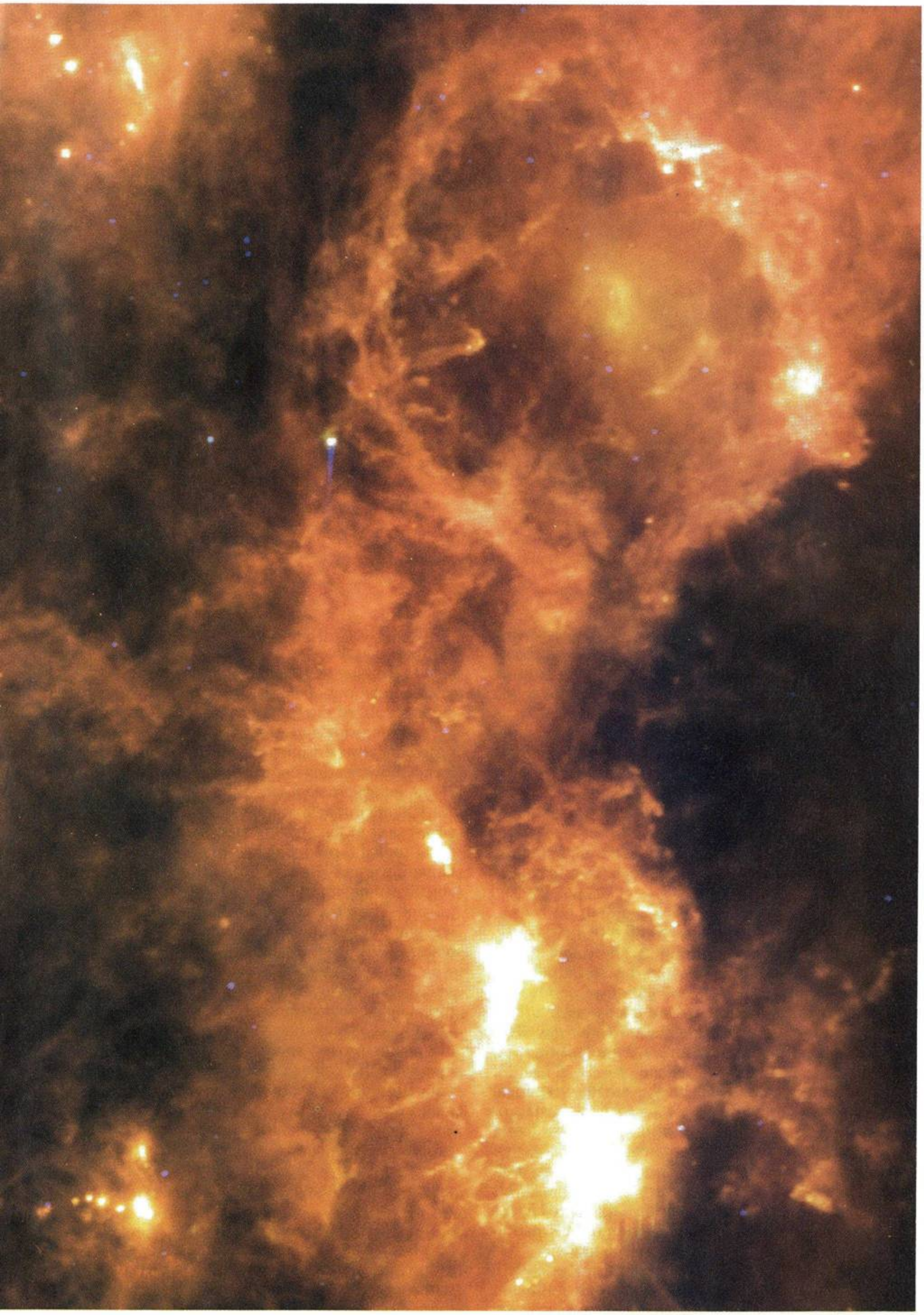
The story begins in 1984, when a team of IRAS astronomers led by Frank Low of Caltech announced the discovery of a new component of the interstellar medium. The IRAS instruments revealed that infrared radiation with a wavelength of 100 microns emanated from much of the sky. At first the astronomers suspected something was wrong with the equipment, but after checking everything thoroughly, they felt confident that what they had found was real. The 100-micron images showed wispy structures that reminded the team of cirrus clouds on Earth, so this stuff quickly came to be called interstellar "cirrus." The structures spanned huge volumes of space, ranging from light-years to many tens of light-years across.

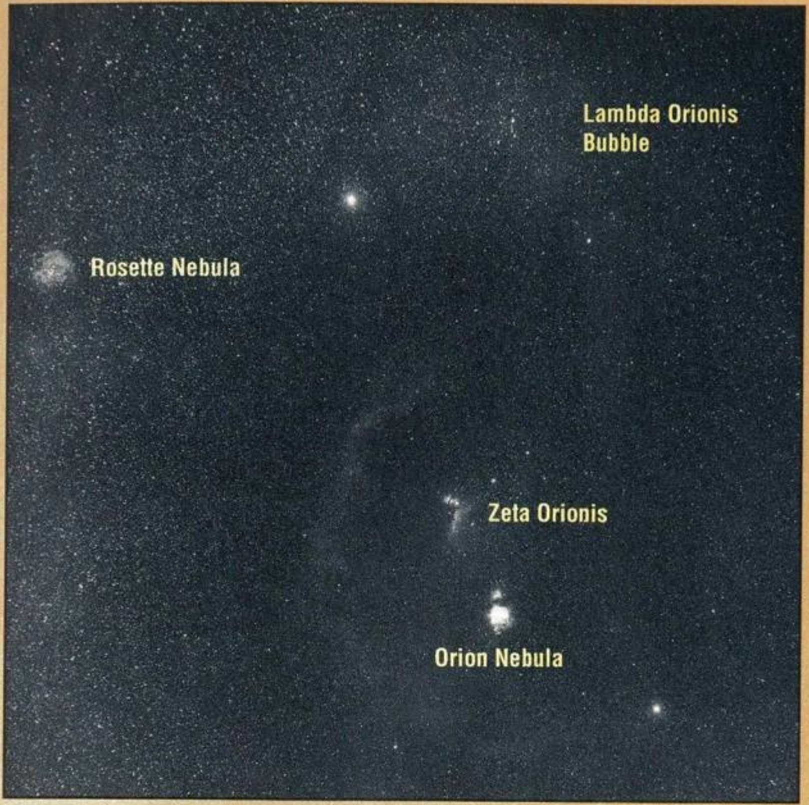
The next step — taking a good look at these structures — posed unexpected and time-consuming challenges. The discovery of cirrus was one thing. Producing clear images of what it looked like was another story entirely.

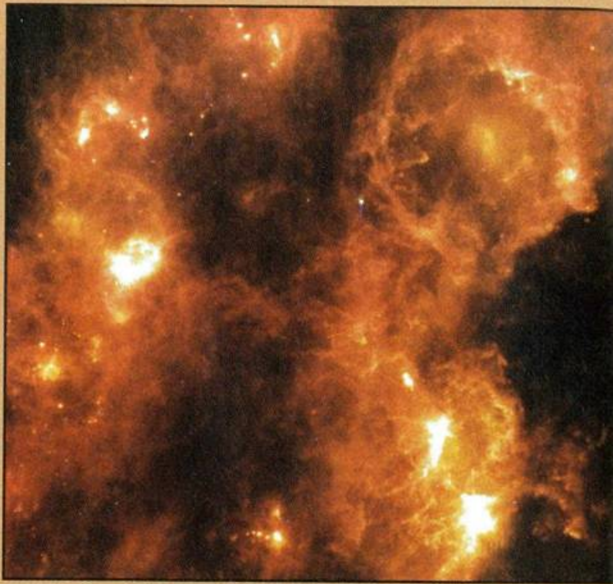
The essence of the problem was that the IRAS designers never intended the satellite to create images. Yet close study of something as widespread as cirrus required pictures to show the full extent of their structure. These pictures could then be compared



ORION COMES ALIVE to the sensitive infrared eye of IRAS. Dominating the image are the Orion Nebula at lower right and the Rosette Nebula at middle left. Just above the Orion Nebula lies the nebulosity surrounding Zeta Orionis, and the large ring at upper right is the remnant of an ancient supernova explosion centered near Lambda Orionis. Image processing by IPAC under contract to JPL.







DRAMATICALLY DIFFERENT VIEWS of Orion arise depending on how you observe it. IRAS's 100-micron observations zero in on the cool, infrared-bright dust and record many wispy structures called cirrus (above). An optical photo (left), on the other hand, records bright stars and hot gas. Photo by Michael Stecker.

with optical photographs and radio images of the distribution of interstellar hydrogen in the same direction as the cirrus. This would yield a better understanding of the relationship among the various components of the interstellar medium.

Undaunted, dozens of astronomers accepted the challenge and labored for years to produce pictures of the infrared cirrus. Some of their results are shown for the first time on these pages. This small gallery of cirrus images will give you an inkling of the beauty present in the infrared sky. But it is what the images reveal about the interstellar medium, the birthplace of stars, that drove astronomers to create the images in the first place.

Weaving an Infrared Picture

It took many years to produce these images because of the way IRAS observed the sky. Unlike an imaging system, in which the telescope points to a specific area and then makes an exposure, the IRAS telescope scanned across the sky day after day. This produced a huge raster pattern of the intensity of infrared emission in four wavelength bands, at 12, 25, 60, and 100 microns. Though these data were ideal for measuring the brightness of infrared-bright stars or distant galaxies, they were terrible for constructing images. Creating an image required weaving together scans taken hours or even days apart. Because individual scans had slightly different background levels due to instrumental effects, stripes appeared across the images. Each change in background level had to be identified, measured, and then removed.

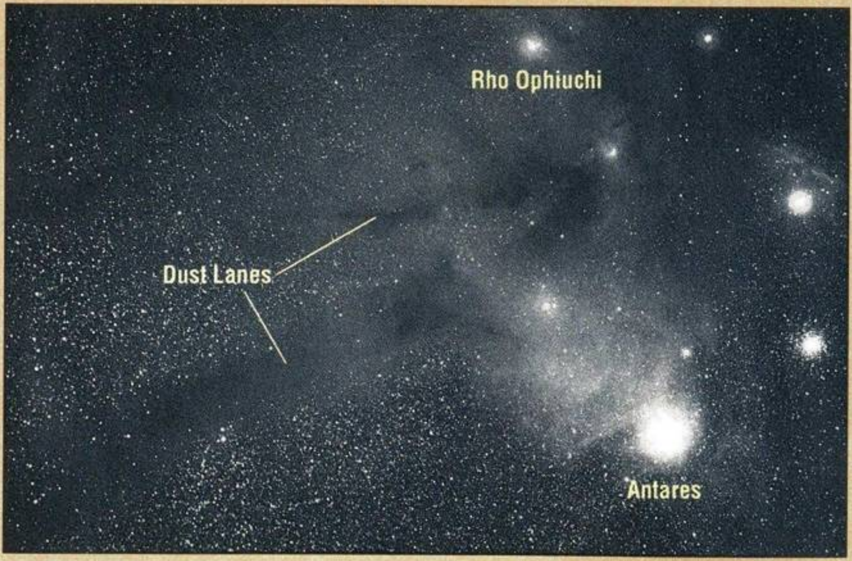
Destriping, as the process came to be called, taxed the ingenuity of even the brightest computer programmers. Learning how to do it correctly took years of effort. It actually became something of a fetish among those working with the IRAS data to be able to destripe better than the next person, and arguments broke out over whose computer programs did the best job. At the same time, astronomers at the Infrared Processing and Analysis Center at Caltech were systematically destriping all the IRAS data. That work is only now nearing completion.

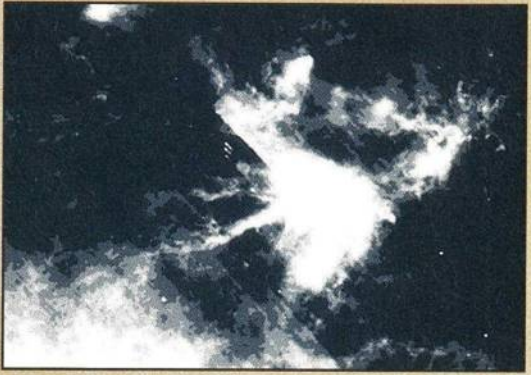
Another problem faced those who wanted to use the 100-micron data from IRAS to make pictures of the cirrus: dust in the solar system. This dust not only reflects sunlight, producing a subtle glow visible to the human eye and known as the zodiacal light, but also absorbs sunlight and then re-emits that energy in the infrared. The glow forms a great swath across the heavens that follows the ecliptic, the apparent path of the planets. This local infrared glow forms a haze through which the infrared radiation from the more distant Milky Way has to shine. Only after subtracting the zodiacal light could astronomers clearly see the cirrus.

Once astronomers overcame all the problems, the results proved spectacular. After destriping and removing the zodiacal contribution, the 100-micron data provided a beautiful new view of interstellar matter. Now dozens of astronomers around the world are concentrating on their favorite regions, trying to explain why the cirrus looks the way it does and how it is associated with hydrogen gas, molecules, magnetic fields, and the structure of the Milky Way.

Clouds of Darkness

Before IRAS discovered the cirrus, dark dust clouds between the stars had been observed only with optical telescopes. One of the best known of these clouds is in the constellation Ophiuchus, where





HOLES IN THE HEAVENS — so thought some early observers of the dust clouds that block distant starlight. An optical photo of Ophiuchus (above) reveals two such dark streamers trailing to the lower left. Photo by Gary Emerson. A 100-micron IRAS image of the same area (right) shows these streamers as bright filaments. Image courtesy Eugene de Geus.

dark lanes of obscuring material block some of the background stars from view. A few clouds can even be spotted with the naked eye, such as the dark lanes in Cygnus and the almost black void near the Southern Cross known as the Coal Sack.

Today it seems almost quaint that for more than a century the dark patches between the stars were believed to be "holes" in the heavens. That notion goes back to Sir William Herschel, who concluded in the late eighteenth century that the holes allowed observers to see into the dark void beyond the stars. In 1910 Edward E. Barnard, pioneer photographer of these dark patches, told of the experiences of an astronomer who one night aimed his small telescope a little north of Antares. "Presently no stars came into the field of his telescope. After watching for some time he finally concluded the sky had clouded over, but on looking out he found it perfectly clear. His telescope had been pointed to this lane (near the star Rho Ophiuchi) and nothing but blank sky had passed." This illustrates how dark these clouds can be.

These clouds are in fact vast, swirling masses of tiny interstellar dust grains made of silicon and carbon and surrounded by water ice laced with organic molecules. These include ethyl and methyl alcohol, formaldehyde, and cyano-acetylene. The grains occupy only a small fraction of the space in a dark cloud, but the clouds are so huge that collectively the tiny particles block starlight from beyond. Thus we see the clouds as dark markings against a bright backdrop of stars in the Milky Way.

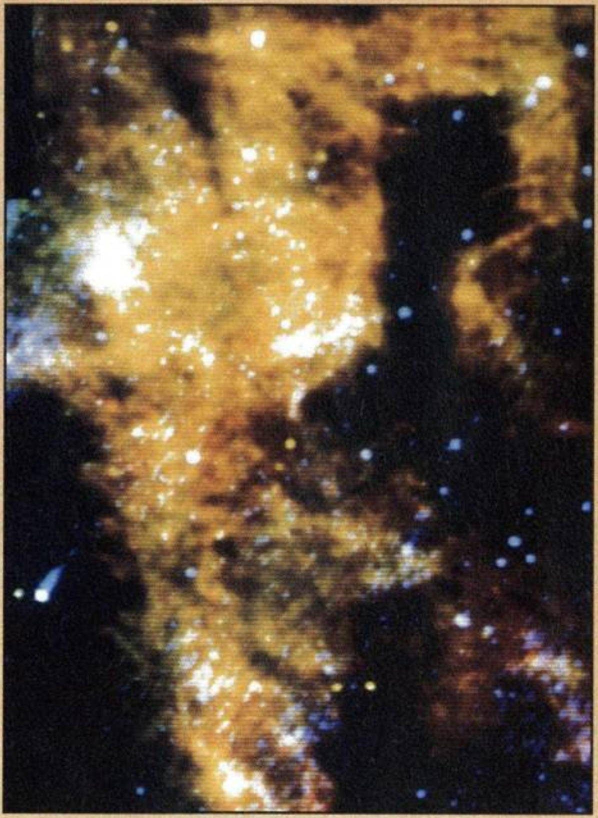
The photos above compare the 100-micron counterpart of the dark clouds in Ophiuchus to an optical view. The bright infrared streamers radiating away from the core of Ophiuchus correspond to the dark dust lanes that intrigued Barnard. Within these filaments, astronomers have observed the infrared glow of low-mass stars in the process of being born.

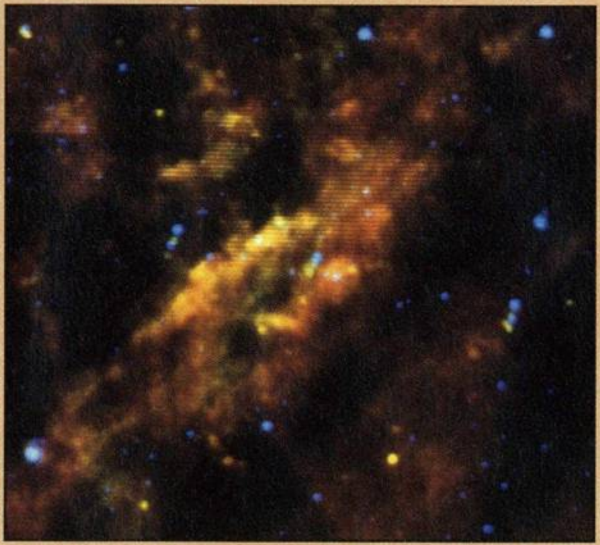
The apparent difference between the dark dust lanes seen in the optical and the bright streamers seen in the infrared arises from the temperature of the dust. Everything in the universe emits some form of electromagnetic radiation. That includes your body which, at a temperature of 295 kelvins (about 20° Celsius), glows brightly in the infrared. That is why infrared-sensitive binoculars can be used to reveal the presence of enemy soldiers on an otherwise pitch black night.

Like all forms of electromagnetic radiation, infrared can be generated by the motion of the particles that make up an object. Because an object's temperature is above absolute zero, motion at the atomic level is always present and the object will emit some radiation at all wavelengths. However, as an object grows hotter, the wavelength at which it emits the most energy becomes shorter. In the case of the Sun's surface, which glows at a temperature of 5,800 kelvins (K), the radiation peaks in the visible part of the spectrum. Interstellar grains, on the other hand, are warmed by starlight to only about 20 or 30 K. At this temperature, they are expected to radiate infrared energy at a wavelength of around 100 microns, and that's exactly what IRAS found.

Blanketing the Sky

No one was surprised that IRAS detected the glow of interstellar dust, at least not the emission coming from the plane of the Milky Way. What came as a shock was that the cirrus appeared all





THE BACKDOOR NEBULA is a cirrus structure with a distinctly rectangular shape (at upper right in photo at left). The bright area to the nebula's left is home to three carbon monoxide-rich clouds. Image courtesy Lee J. Rickard, Fran Verter, and Barry Turner. Cirrus filaments abound in the Eridanus region (above). Image courtesy Lee J. Rickard.

over the sky. Though interstellar dust is present in small quantities everywhere in the Galaxy, before the age of IRAS, it could only be seen against the bright background of stars in the Milky Way. Diffuse stretches of this material well away from the Milky Way, where the number of background stars is much lower, essentially remained invisible, even in long exposure photographs.

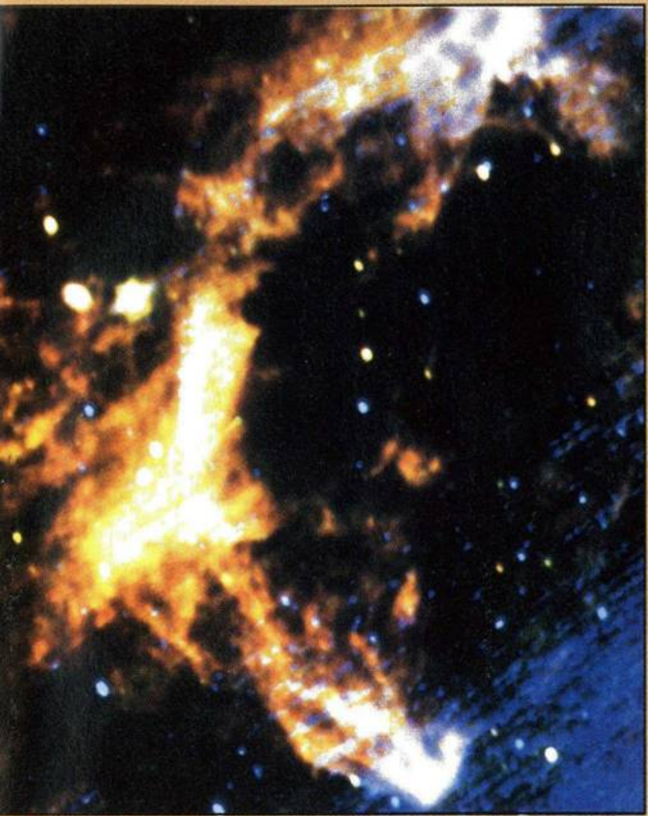
In displaying the IRAS data, astronomers typically have assigned each of the wavelength channels a different color and then combined them into one image. In most cases, the long wavelength, 100-micron emission is colored red while the short wavelength, 12-micron emission is made blue. Green is used for the 60-micron emission. A blue dot in an image is usually a star that shines brightly in the infrared, often because it is surrounded by dust at a temperature of a few hundred kelvins. A slightly green spot is likely to be a galaxy (galaxies tend to glow brightest in the infrared at 60 microns). The wispy red structure in the multicolor images is the cirrus. Depending on its temperature, the cirrus may produce relatively more 12-micron emission and then appear white in the image.

The centerpiece of the photo above is a cirrus structure called the Backdoor Nebula. Its rectangular shape and nearly straight sides have intrigued Lee J. Rickard of the Naval Research Laboratory, Fran Verter of the Goddard Space Flight Center, and Barry Turner of the National Radio Astronomy Observatory. The appearance of the structure is purely fortuitous; still, they have been heard to joke that this doorway may offer us a view into another dimension.

The bright area to the left of the Backdoor Nebula contains three carbon monoxide-rich "clouds." First spotted by University of Maryland graduate student Loris Magnani, these clouds are better understood today because of the satellite's observations. Before IRAS began its survey, Magnani took a close look at the Palomar Sky Survey plates, searching for and finding many previously unrecognized and very faint veilings of dust cutting off light from distant stars. Next he and his collaborators Leo Blitz and Lee Mundy looked in those directions for the radio signature of carbon monoxide molecules. Their radio survey turned up carbon monoxide virtually everywhere they looked, in all of the 50 or so previously unnoticed clouds. But it was the 100-micron data from IRAS that revealed the nature of these structures in glorious detail.

Because carbon monoxide is not a particularly stable molecule, it gets destroyed easily when exposed to starlight. Its presence, therefore, indicates that something is shielding it from starlight, namely, interstellar dust. IRAS confirmed the existence of this dust when it found the 100-micron emission from cirrus associated with the carbon monoxide structures observed by Magnani, Blitz, and Mundy. Since then radio astronomers have found in these structures other molecular species, such as ammonia and formaldehyde.

Rickard and his colleagues also detected weak formaldehyde absorption at the Nebula's edge, in areas of apparently low density. Because formaldehyde can only absorb radio signals when it is gathered in very dense clumps, this discovery meant that the cirrus is filled with tiny, dense patches that are invisible in the 100-micron images. Some astronomers think these clumps may represent the very earliest stages of star formation, when interstellar gas and dust are just beginning to swirl around. Gravity would then begin



A RING OF CIRRUS dominates part of Ursa Major (left). The brightest emission in this IRAS image coincides with clouds of carbon monoxide. Courtesy F. Desert and F. Boulanger. The galactic plane is defined by the prominent cirrus structure seen in this view of the 100-micron emission from about one-third of the Milky Way Galaxy (below). Courtesy Lee J. Rickard, who used the data file produced by F. Boulanger.

to pull on the gas and dust so as to draw the matter together to the point where star formation can be initiated, perhaps a few million years hence.

Among the photos above is a particularly striking one that shows cirrus filaments at the southern end of a huge ring of dust and gas (about 35° in diameter) called the Eridanus shell. At its northern end, Barnard's Loop, just northeast of the Orion Nebula, defines its boundary. These cirrus filaments are associated with both cold (50 K) and hot (10,000 K) hydrogen gas filaments, the former seen with radio telescopes and the latter with optical telescopes. This complex shell structure apparently was created long ago by the combined action of supernovae in the star-forming region in Orion. Strong ultraviolet radiation streaming out of the young stars in Orion keeps this vast cavity excavated and some of the interstellar matter is pushed into filaments along its outside edge.

Down to the Nitty-Gritty

Just what is the cirrus dust made of? French astronomers F. X. Desert, F. Boulanger, and J. L. Puget have used the IRAS data in combination with theoretical models of how dust obscures starlight to conclude that a typical cirrus structure contains grains of at least three distinctly different sizes. Most of the grains are relatively large, between 10 and 100 millionths of a millimeter across, though still tiny by human standards. The rest is in the form of even smaller grains (between 1 and 10 millionths of a millimeter in size) and polycyclic aromatic hydrocarbons, giant molecules based on carbon chains. Each of these molecules contains hundreds of atoms and is less than one millionth of a millimeter in diameter. The bigger grains are made of silicates surrounded by water ice containing various metals and complex molecules. The smaller grains are carbon-rich.

Individual astronomers continue to use the IRAS database to extract the information they need to make images of their favorite regions. At the same time, astronomers at the IRAS data analysis centers in the United States and Europe are working to complete the task of systematically removing the zodiacal light and destriping the data. Within a year or so, astronomers will be able to study the 100-micron cirrus as readily as they might photograph an area of sky with a telescope.

The main difference between photographing the visible sky and studying the infrared heavens will be that the infrared sky resides inside a computer, which will allow you to produce images on a video monitor. Those images will be like those shown here, and they can be analyzed to provide information on the temperature, density, and structure of the dust. This information will pave the way for a comprehensive understanding of how matter between the stars gathers into blobs that will someday form stars.

The saga of producing images from the IRAS data has been one of overcoming obstacles. Astronomers from many nations have collaborated to figure out how to destripe the data and remove the zodiacal emission to produce images undreamed of when the satellite was launched. Their work gives us a wonderful new view of what matter between the stars really looks like. ☐

Gerrit L. Verschuur is a radio astronomer and author living near Bowie, Maryland. His last article for ASTRONOMY *was "The End of Civilization" in the September 1991 issue.*

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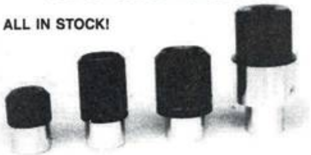

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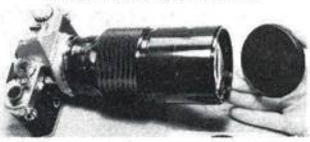

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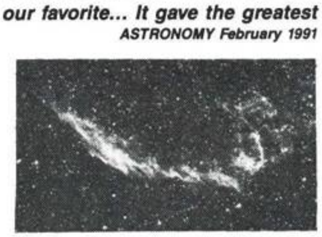

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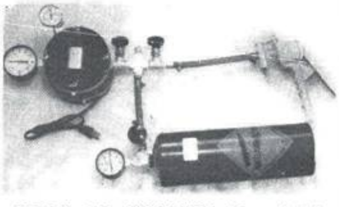

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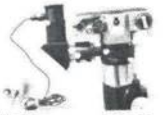

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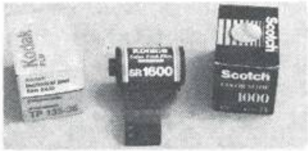

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Only the LUMICON SKY VECTOR II has size, **true visual magnitude**, and complete **detailed visual description** for **all** 1500 objects in memory.

NGC SKY VECTOR™ $699

IMPROVED!—1731 Additions/Corrections

NGC-Sky Vector
LUMICON

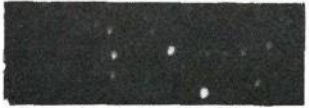
Improved NGC SKY VECTOR with over 8,000 object memory including complete and corrected RNGC catalogue, and IC and planetary catalogues.

LUMICON NGC SKY VECTOR FEATURES:

- *All features of* LUMICON SKY VECTOR II
- Complete *corrected* RNGC catalogue
- 574 nonexistent NGC objects identified
- 343 corrections to RNGC catalogue
- 203 best colored & multiple stars
- 140 "Best IC Objects" catalogue
- 306 best planetary nebulae selected by Jack Marling in separate catalogue listing
- 268 best "Non NGC/IC" objects catalogued
- *"IDENTIFY" program helps you identify* an unknown object seen in eyepiece
- "GUIDE" program leads you to object
- Detailed visual or photographic descriptions
- RS-232 port for computer access
- Includes planets' ephemerides in computer

Specify Telescope Type: Meade 2045, 2080, 2120, C-8, C-11, Odyssey 8, 10, 13, 17½, Alt-Azimuth.
Ultima 8, 11 .. **add $25**, C-14 .. **add $75**

COMA CORRECTOR



Coma 1 inch off-axis 17½" f/4.5

Same field with LUMICON coma corrector; smaller, more numerous stars.

This computer-designed LUMICON 2" lens reduces coma and flattens the field for both viewing and photography. **It *threads into LUMICON 2" EASY-* GUIDERS for effortless installation.** This lens is optimized for f/4.5 and reduces aberrations for f/3.5 to f/5 Newtonians. Off-*axis images are much smaller, making off-*axis guiding far easier and yielding round pinpoint star images in photos. Since star images are sharp over a full 2¼" circle, you can use medium format cameras in addition to 35mm cameras. This zero power lens does not change image scale nor shift focus, and all lens surfaces are multi-coated for highest efficiency. Although designed for photography you may also use this lens to improve image quality in wide-field viewing with low power eyepieces. Clear aperture = 1.8".

LUMICON Coma Corrector/Field Flattener Lens	**$285.00**
LUMICON 2" EASY-GUIDER	**$169.50**
2" EASY-GUIDER (Mamiya 645)	**$199.50**
2" Adapter for Pentax 6x7	**$85.00**
2" Adapter for Hasselblad	**$185.00**
2" Adapter for Bronica SQ-A	**$175.00**
2" Extension for viewing	**$26.00**

2" DELUXE BARLOW

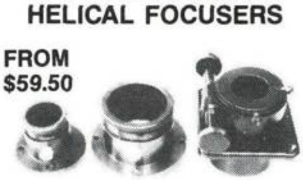
1.8x Multiplier Lens (2" Barlow)

The computer-designed LUMICON 2" Multiplier/Field Flattener multiplies the image scale in photography by 1.8x (f/4.5 becomes *f/8). Use it with any LUMICON 2" EASY-*GUIDER. Guide-stars also become much sharper to make guiding easier. This lens is optimized for f/4.5, but will work well with any optical system. It may also be used visually as a highly corrected 2" Barlow lens.

LUMICON 1.8x Multiplier Lens (2" Barlow) **$235.00**

NEW! LOW PROFILE HELICAL FOCUSERS

FROM $59.50



LUMICON® LOW PROFILE FOCUSERS

LUMICON now offers 3 different low-profile helical focusers. They stand only 1¼-1½" above the telescope tube. Use the 1¼" or 2" versions for viewing. Use the 2" non-rotating focuser for convenient photography with the LUMICON 2" EASY-GUIDER™.

Select your desired base-plate shape! Flat, 7" OD, 9½" OD, 12½" OD, 16" OD, 21" OD.

LUMICON 1¼" Helical Focuser	**$59.50**
LUMICON 2" Helical Focuser 1½" high	**$65.00**
LUMICON Non-rotating Helical Focuser	**$89.50**
2" rack & pinion focuser, only 2" high	**$139.00**
3 handles for non-rotating focuser	**$12.95**
2"/1¼" adapter w/48mm filter threads	**$20.00**
2" LUMICON EASY-GUIDER	**$169.50**

LUMICON 50mm, 80mm SUPER-FINDER™

Visual Astronomers prefer the LUMICON 80mm SUPER-FINDER™, since hundreds of deep-sky objects, including most Messier objects, are visible directly. SUPER-FINDERS also make nice small portable telescopes. 80mm aperture, F=300mm coated achromat or 50mm, F=200mm coated achromat. Eyepieces and/or star diagonal are extra.

1¼" 50mm Finderscope **$59.50**, right-angle	**$89.50**
1¼" straight-thru 80mm SUPER-FINDER	**$169**
1¼" right-angle 80mm SUPER-FINDER	**$179.50**
1¼" right-angle version, w/star diagonal	**$209**
25mm Cross-hair 1¼" eyepiece (12X)	**$39**
1¼" Star Diagonal **$39**, Mounting Brackets,	**$37**
1¼" Amici Prism diag. for correct left-right views	**$69.50**

2" ADAPTERS MEADE, CELESTRON TELESCOPES

These adapters convert refractors and Schmidt-Cassegrain telescopes for 2" operation. *They allow use of 2" accessories, such* as the LUMICON 2" EASY-GUIDER for photography. They also allow use of 2" eyepieces and/or 2" star diagonal for viewing.

2" adapter for C-8, Meade 2080, etc.	**$26.00**
2" adapter for C-80, C-100 refractor	**$39.50**
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2" LUMICON EASY-GUIDER (state camera)	**$169.50**

BURSTING WITH SURPRISES

Recent GRO observations unexpectedly show that gamma-ray bursters likely blaze away from enormous distances.

by Richard Talcott

● ●

Nearly once a day, a short, violent burst of gamma rays arrives at Earth from somewhere in the cosmos. What causes the bursts is still a deep mystery, but recently astronomers have at least found where the sources are. The only problem is that the "bursters" appear to spread uniformly across the sky. And this implies that they lie forbiddingly far away, in the outer reaches of the universe.

That's the startling conclusion drawn from the first several months' results returned by the Burst and Transient Source Experiment onboard NASA's Gamma Ray Observatory (GRO). This finding is a surprise because it contradicts both earlier studies on the distribution of gamma-ray bursts and the expectations of a large number of astronomers. Now theorists must come up with new ideas to explain the origin of these dynamic events.

Few objects in the astrophysical zoo are as mysterious and intriguing as gamma-ray bursters (see "A Burst of Gamma Rays," October 1991). Some spew out vast quantities of gamma rays — the most energetic form of electromagnetic radiation there is — in the blink of an eye. Others radiate their energy more slowly, though even the longest bursts last only a few hundred seconds.

Even stranger, gamma-ray bursters shine almost exclusively at gamma-ray frequencies. Other energetic objects typically radiate at a broad range of frequencies, but no radio waves, infrared radiation, visible light, or ultraviolet emission accompany a gamma-ray burst. Only a few isolated gamma-ray bursts show any X-ray emission at all, and that emission is weak.

The task facing astronomers is to discover a process that in mere seconds can generate huge amounts of very-high-energy radiation while producing little or no low-energy radiation. Despite the formidable challenge, until the GRO observations, astronomers thought they had a good candidate for the source of gamma-ray bursters — neutron stars in our Galaxy.

A neutron star is one of the endpoints of stellar evolution. For a star that begins life with more than about 8 times the Sun's mass, nuclear fusion eventually leads to a star with an iron core. This dense core is then crushed further when the star explodes as a supernova. The resulting object — a neutron star — is a tiny sphere about 10 kilometers in diameter packed with twice as much mass as the Sun.

If gamma-ray bursts arise from neutron stars, the sky positions of the bursts should provide supporting evidence. Specifically, because neutron stars congregate in the disk of the Milky Way Galaxy, more bursts should emanate from the plane of the Galaxy.

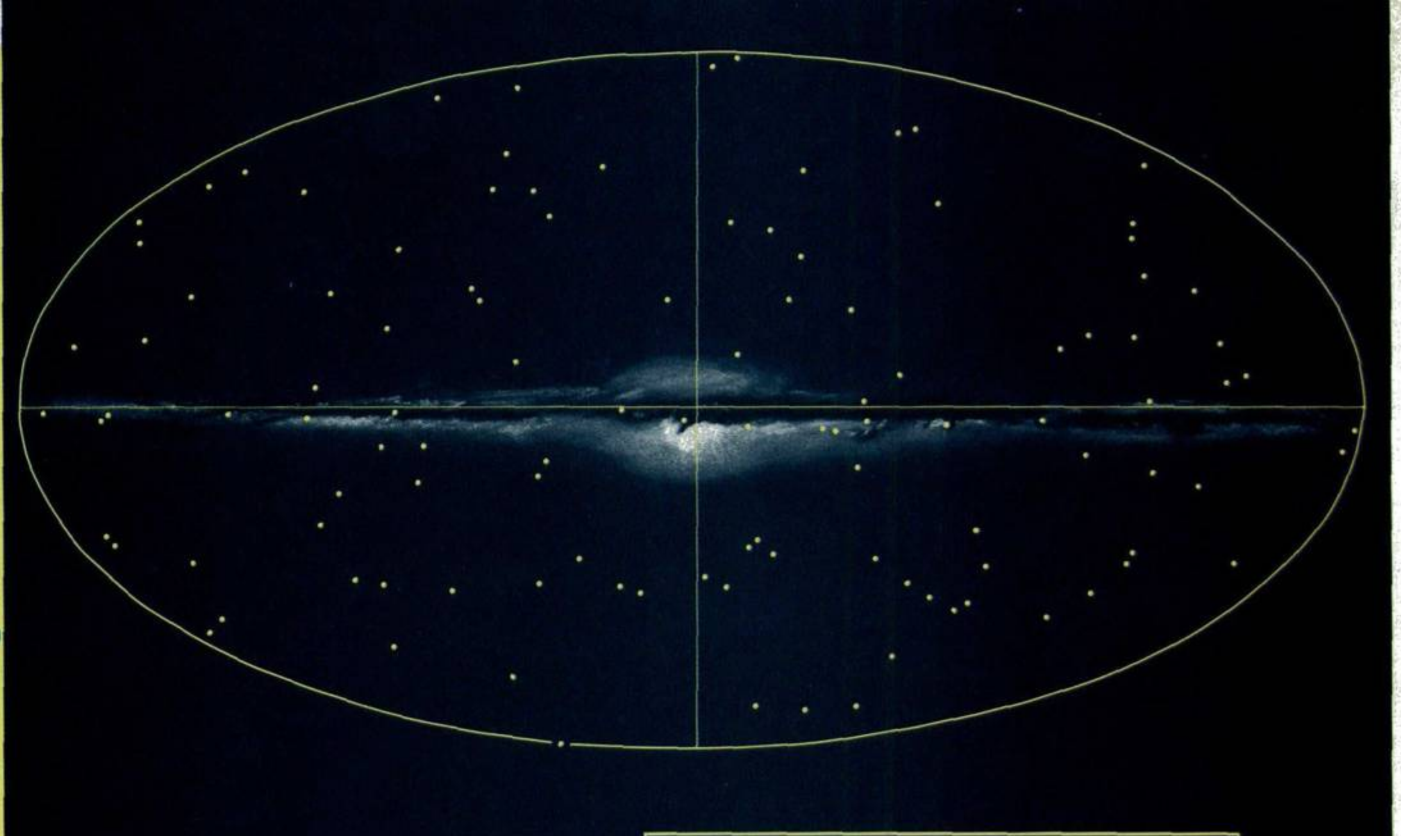
Over the past twenty years or so, a host of satellite-borne detectors (gamma rays cannot penetrate Earth's atmosphere) have recorded a few hundred gamma-ray bursts. Though none of the detectors had high sensitivity or directional accuracy, the observations did provide a few tantalizing clues.

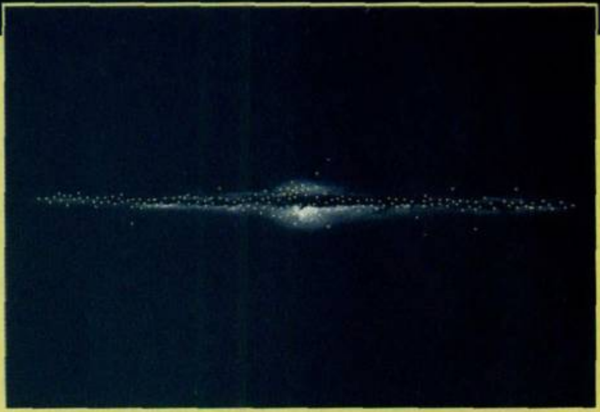
Last year, a team of French and Soviet astronomers announced that 27 weak gamma-ray bursts detected by the Venera 13 and 14 spacecraft lay preferentially along the galactic disk. And spectral observations of gamma-ray bursts made with the Japanese Ginga satellite showed in a few instances features that could be explained if they were generated in a magnetic field of roughly a trillion gauss — what you'd expect in a neutron star's magnetic field.

The launch of the Gamma Ray Observatory last April has given astronomers their best view yet of gamma-ray bursters. The puzzle is that the GRO results run counter to what astronomers expected.

During the first seven months of the mission, GRO recorded slightly fewer than one gamma-ray burst per day (a total of 184 in 266 days as we went to press). That's enough events to show whether there is any clustering of the bursts, either along the galactic disk or in some other direction. As you can see from the data (opposite page), there is no significant clustering — gamma-ray bursts appear to come from all directions in the sky.

That leaves the advocates of neutron stars as gamma-ray-burst sources with a serious problem: How can events arising on neutron stars be distributed uniformly while the neutron stars themselves, which cluster in the Galaxy's disk, are not?





GAMMA-RAY BURSTS SPREAD EVENLY across the sky (above, shown in galactic coordinates), implying they erupt from objects deep in the universe. GRO data courtesy Gerald Fishman. If the bursts arose in our Galaxy, as previously thought, they would cluster along the galactic plane (right, hypothetical distribution).

The simple answer is that they can't be. To make the neutron-star model work now, there has to be a large number of neutron stars scattered throughout the Galaxy's halo. Not only is it unlikely that many neutron stars formed in the galactic halo, but also this model would require a halo several times larger than those observed around other galaxies. The neutron-star model also runs into a problem because GRO's spectrometers have failed to find evidence of the spectral lines that magnetized neutron stars emit.

If neutron stars in the Galaxy don't produce gamma-ray bursts, what does? The most straightforward conclusion is that gamma-ray bursters are not associated with our Galaxy and instead are spread evenly throughout the universe. If true, this means that gamma-ray bursts must be among the most powerful events in the universe.

Theorists are just beginning to look at processes that could release this much energy. In one recently suggested scenario, a stellar-mass black hole collides with a neutron star, releasing a flood of gamma rays in the process. A second proposal, in which two orbiting neutron stars spiral into one another and coalesce, could also produce the observed gamma rays. If this happened in each galaxy once every 100 million years, enough bursts would occur to match the observed rate.

An alternate way to explain the GRO observations is much less appealing. The gamma-ray bursts could originate right in our own backyard, so to speak. Events in our local neighborhood of the Galaxy could give rise to the observed distribution. The problem with this scenario is that no one has the foggiest idea what nearby objects could cause gamma-ray bursts. It also would be extremely disconcerting to find out that we had missed such a significant component of the Sun's neighborhood.

Last fall GRO was renamed the Arthur Holly Compton Gamma Ray Observatory, after the Nobel-prize-winning American physicist (1892-1962) who in 1923 first described how high-energy radiation interacts with matter. In just a few short months, the observatory has achieved some remarkable results by exploring objects Compton himself could scarcely dream of. If the Compton Gamma Ray Observatory continues to perform flawlessly, we can look forward to furthering our knowledge of gamma-ray bursters as well as the other wonders of the gamma-ray sky. □

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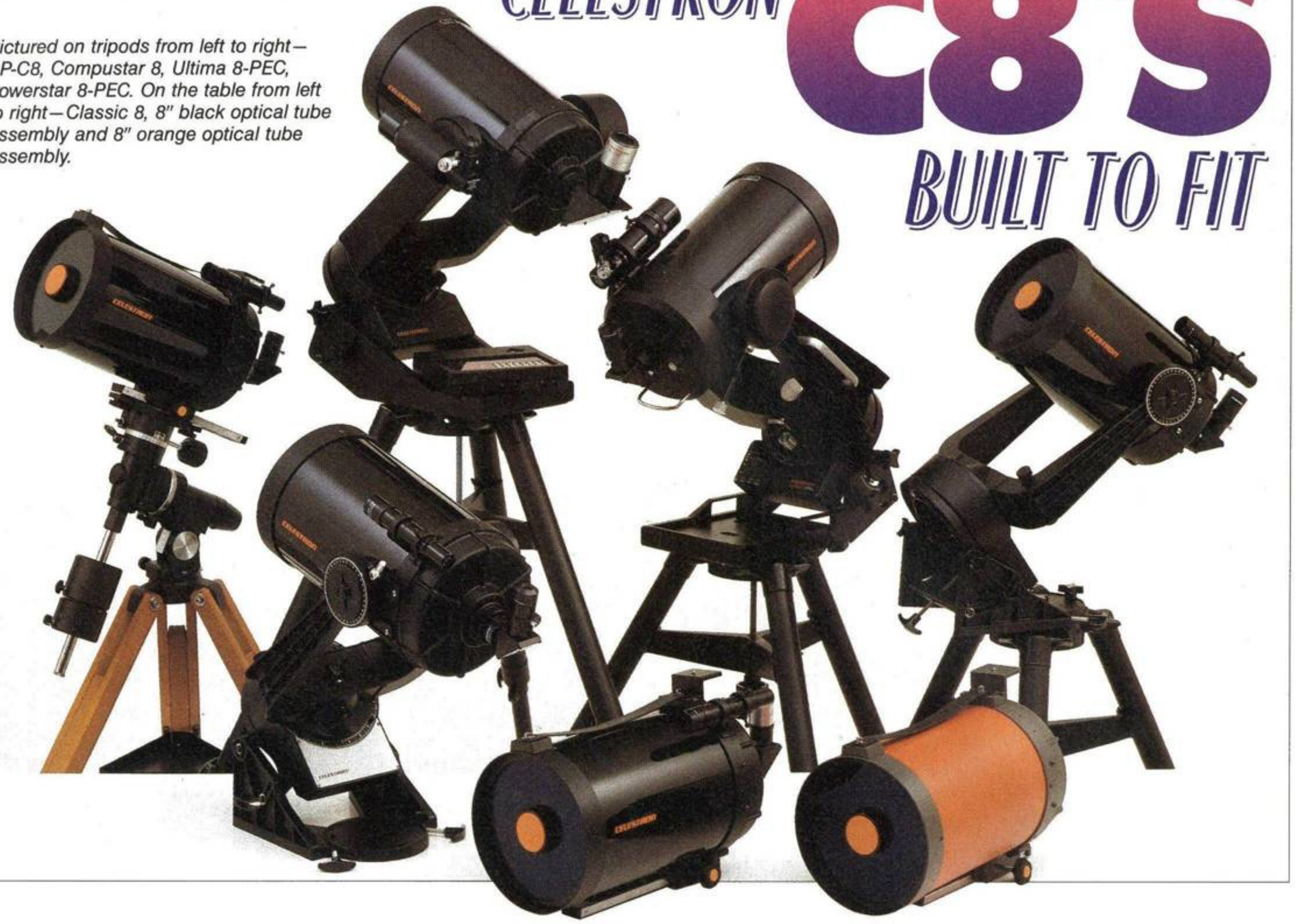

Pictured on tripods from left to right—SP-C8, Compustar 8, Ultima 8-PEC, Powerstar 8-PEC. On the table from left to right—Classic 8, 8" black optical tube assembly and 8" orange optical tube assembly.

Since 1970, Celestron's 8-inch Schmidt-Cassegrains have continued to grow in popularity. They have become so popular, that a whole family of C8's has evolved. We've built them to fit different tastes, different needs and different budgets.

But all are built with Celestron's same dedication to providing the *finest quality available*. Quality evidenced in the optics (judged best in magazine comparison studies), the sturdy mechanics and the extensive array of optional accessories.

All of our C8's share the same American-made f/10 optical system. For a dual f/6.3, f/10 system, add Celestron's new reducer/corrector accessory. Starbright® optical coatings are standard on all C8's (optional on Super Polaris C8). And all carry a **limited lifetime warranty.**

CLASSIC 8

For the budget conscious, we offer the Classic 8. Supplied with a standard wedge, it works well on a sturdy table. An optional tripod is available but not mandatory. Runs off AC power. Spur gear system.

SUPER POLARIS C8

Another economical choice, this C8 is supplied on a Super Polaris equatorial mount and includes an adjustable wood tripod. This deluxe German mount utilizes 144 tooth lapped worm gears and features a built-in illuminated polar alignment scope. Available with standard coatings or with Starbright® coatings.

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For seasoned observers, a chance to see more. For novices, a help in finding objects. For educators, the ultimate teaching tool. Explore over 8000 objects contained in this C8's microcomputer memory. Totally integrated system with unlimited possibilities. Includes 2" accessories.

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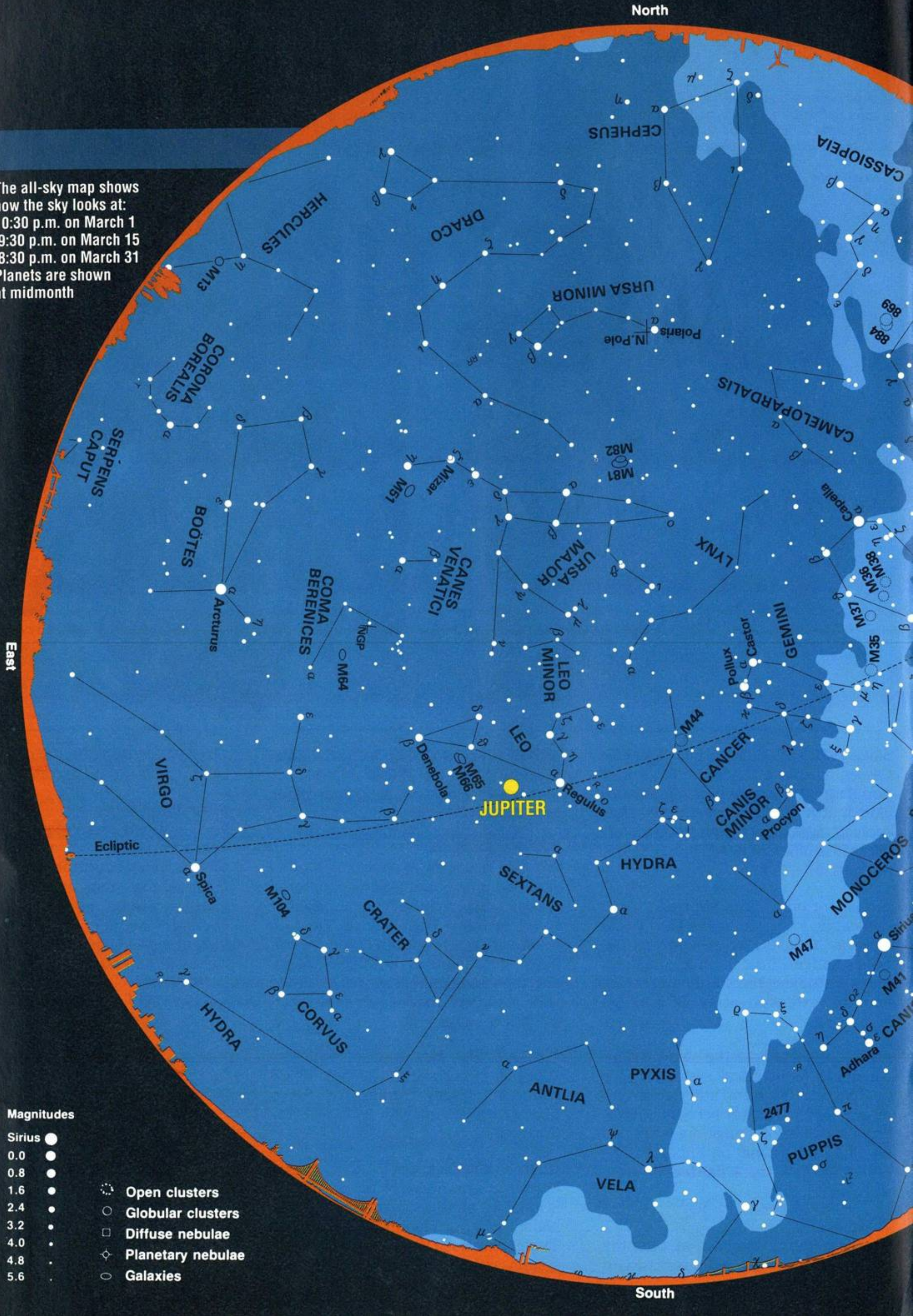
The all-sky map shows how the sky looks at:
10:30 p.m. on March 1
9:30 p.m. on March 15
8:30 p.m. on March 31
Planets are shown at midmonth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East
South
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CASSIOPEIA
HERCULES
DRACO
M13
URSA MINOR
Polaris
N.Pole
869
884
CORONA BOREALIS
CAMELOPARDALIS
SERPENS CAPUT
M82
M81
M51
Mizar
Capella
BOÖTES
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COMA BERENICES
M36
M38
M37
Arcturus
NGP
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M64
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Spica
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M104
CRATER
M47
Sirius
M41
HYDRA
CORVUS
CANIS
Adhara
PYXIS
ANTLIA
2477
PUPPIS
VELA
Magnitudes
Sirius
0.0
0.8
1.6
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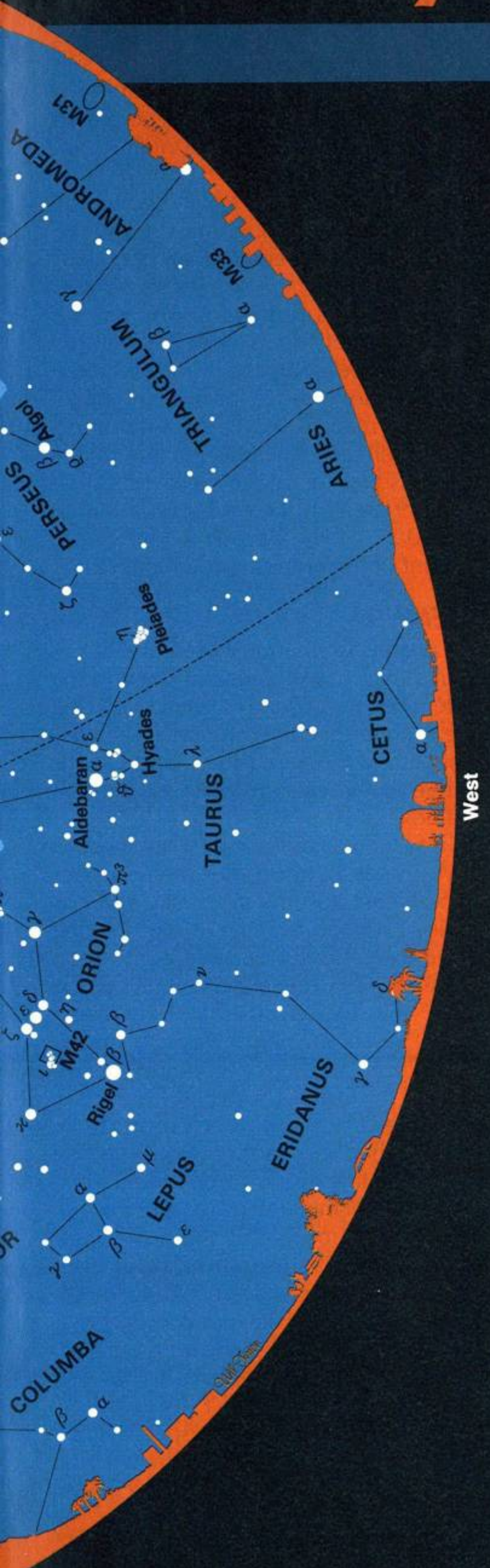
5.6
Open clusters
Globular clusters
Diffuse nebulae
Planetary nebulae
Galaxies

Sky Almanac



March 1992

MERCURY AT ITS BEST

As the planet closest to the Sun, Mercury never appears far from our star's blinding light. But for Northern Hemisphere observers, this month is the best of the year for viewing Mercury in the evening sky. You can find the –0.3-magnitude planet low in the west half an hour after the Sun sets for several days around its March 9 greatest elongation.

JUPITER RULES THE NIGHT

The largest planet is now visible low in the east as darkness falls. Shining brilliantly at magnitude –2.5, Jupiter is the brightest point of light in the sky until Venus rises at the approach of dawn.

THREE PLANETS AND THE MOON

The southeastern morning sky is the place to watch this month for a spectacular gathering of solar system objects. Venus, Mars, and Saturn lie close to one another throughout early March, but be sure to check the view on March 1, when the slender crescent Moon also lies close by.

VESTA AT OPPOSITION

The brightest of the asteroids reaches opposition on March 8/9, when it lies near the 2nd-magnitude star Denebola in Leo. Although 6th-magnitude Vesta is bright enough to see with the naked eye from a dark-sky site, your best bet for viewing the minor planet is to use binoculars or a telescope.

Calendar of Events

1 The Moon passes 4° north of Mars, 1 p.m. EST
The Moon passes 4° north of Saturn, 8 p.m. EST
2 The Moon passes 4° north of Venus, 1 a.m. EST
4 New Moon is at 8:22 a.m. EST
6 The Moon passes 4° north of Mercury, 1 a.m. EST
Mars passes 0.4° south of Saturn, 8 a.m. EST
8 Juno is in conjunction with the Sun
Vesta is at opposition
9 Mercury is at greatest eastern elongation (18°)
11 First Quarter Moon is at 9:36 p.m. EST
16 The Moon is at perigee (225,192 miles from Earth), 12:41 p.m. EST
18 Full Moon is at 1:18 p.m. EST
20 Vernal equinox is at 3:48 a.m. EST
25 Last Quarter Moon is at 9:30 p.m. EST
26 Mercury is in inferior conjunction
28 The Moon is at apogee (251,596 miles from Earth), 9:16 a.m. EST
29 The Moon passes 4° north of Saturn, 9 a.m. EST

Map Art by Wil Tirion

Eye on the Sky

by Deborah Byrd

JUPITER BRIGHT AND EASY TO FIND

As darkness falls in early March, you can see a bold white object shining low in the east. This is Jupiter, the largest planet in the solar system. Because it reached opposition at the end of February, Jupiter is now nearly as close and as bright as it will get in 1992. The planet shines at magnitude –2.5, dominating the sky nearly all night, until Venus rises shortly before dawn.

At the beginning of March, Jupiter lies about 10° from Regulus, the brightest star in Leo. If you watch carefully throughout the month, you'll see Jupiter creep closer to Regulus. By the end of March, only 6° separate the planet and star.

Many of you may know that Jupiter's largest moons can be glimpsed with steadily held binoculars. What you may not know is that Jupiter's largest moon, Ganymede, can be glimpsed with the naked eye. We don't see it routinely because it lies close to the brilliant planet and gets lost in the glare. To spot Ganymede, observe on a moonless night from a dark-sky site when the satellite lies near its maximum distance from Jupiter. (The best times this month are the nights of March 1/2 and 5/6, the mornings of March 9 and 13, the evenings of March 22 and 26, and the night of March 30/31.) If you have excellent vision, Ganymede will appear as a tiny point of light right beside Jupiter.

MERCURY BRIGHT IN THE EVENING

The most elusive of the bright planets is innermost Mercury. But in early March, Mercury is less elusive than usual, appearing low in the west after sunset. For Northern Hemisphere observers, Mercury's best evening apparitions always come around this time of year. That's because the ecliptic — the apparent path of the Sun, Moon, and planets — makes its steepest angle relative to the western evening horizon around the time of the vernal equinox.

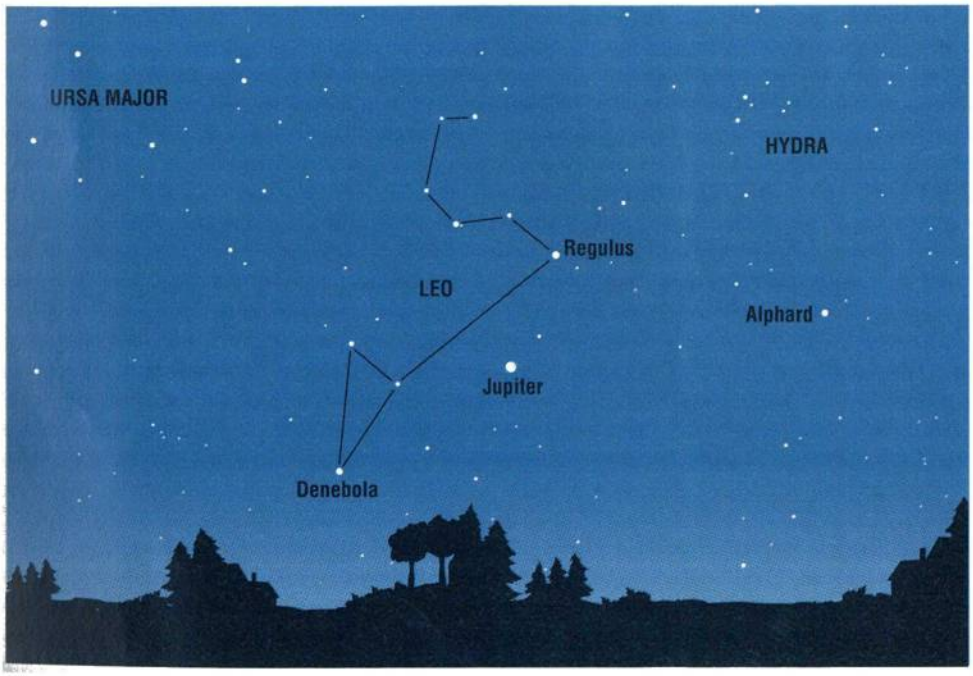
The trick to spotting Mercury is to be outside, scanning the western horizon, shortly after sunset. If you wait an hour after the Sun goes down, you've waited too long. The planet lies low in the sky and any low cloud or haze hides it from view. A good evening to start looking for Mercury is March 5, when the exceedingly thin crescent Moon sweeps near. The two are so captivating — so fragile and tentative in the soft twilight — that if you don't see them right away, be sure to scan for them with binoculars.

On March 9, Mercury reaches greatest elongation, when it is farthest from the Sun for this evening apparition. Then the planet lies 18° east of the Sun and appears 11° above the western horizon half an hour after sunset for observers at 40° north latitude. As the month progresses, Mercury plunges toward the horizon like a shy actor who has said his lines and can't resist rushing offstage. The planet speeds along in its orbit so rapidly, in fact, that by the end of the month it passes between the Sun and Earth.

A SPRINGTIME FULL MOON

The Full Moon this month falls on March 18. This is the Full Moon closest to the equinox, which arrives at 3:48 a.m. EST

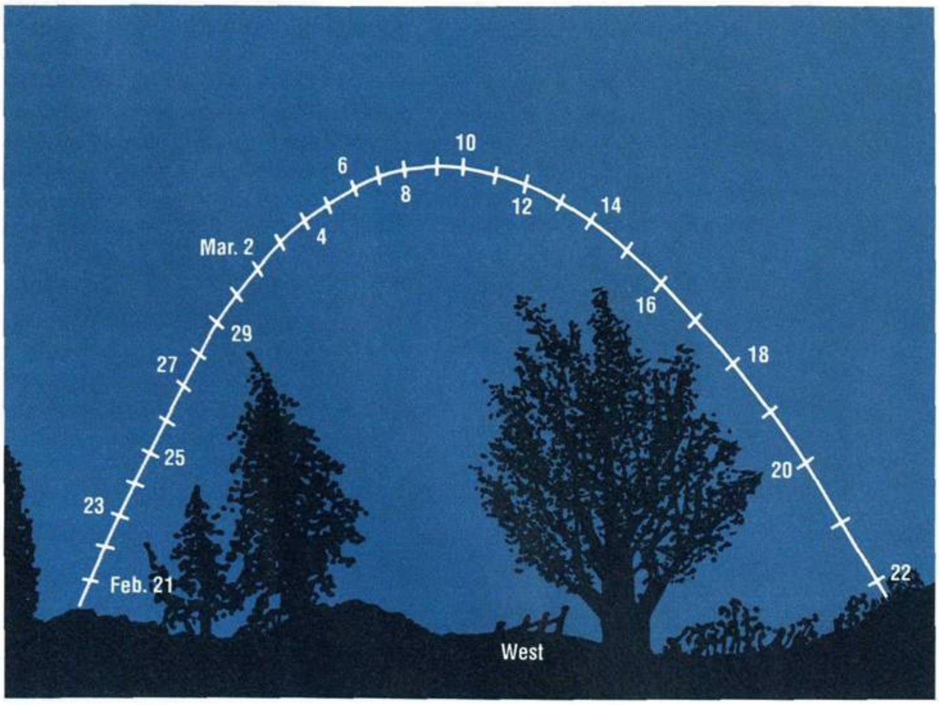
JUPITER DOMINATES the evening sky throughout March. As twilight comes to a close, it's the brightest point of light in the east, where it lies below the familiar constellation Leo.



on March 20. The March Full Moon is sometimes called the Sap Moon, Crow Moon, or Lenten Moon. Like the Sun at the equinox, it casts its light for almost exactly 12 hours.

The pattern of rising for the March Full Moon is just the opposite of the pattern for the September Full Moon. That September Moon — the legendary Harvest Moon — is famous for rising each evening only a short time later than the night before. The unusually short time lag between moonrises for the Harvest Moon stems from the narrow angle that the ecliptic makes with the eastern horizon in the autumn evening sky.

The Full Moon in March, on the other hand, finds itself on an ecliptic that stands nearly straight up relative to the eastern horizon in the evening. Normally the Moon rises about 50 minutes later each night, but near the March equinox the Full Moon rises more than an hour later.



MERCURY'S BEST APPEARANCE in the evening during 1992 reaches its peak in March. The innermost planet is easiest to see on the 9th, when it lies 11° above the western horizon 30 minutes after sunset.

MARCH'S PLANETS

During the first half of March, **Mercury** appears low in the west shortly after the Sun sets. At greatest elongation on March 9, the planet shines brightly at magnitude –0.3. It fades rapidly after that, as it prepares to pass between the Sun and Earth on March 26. Mercury will return to the predawn sky in April.

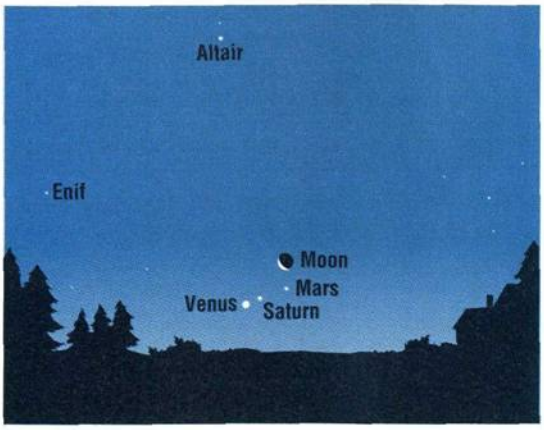
The brightest object during the evening and most of the morning this month is –2.5-magnitude **Jupiter**. Watch for the giant planet on the night of March 16/17, when it lies near the almost Full Moon. The bright star nearby is Regulus, the "heart of the lion" in the constellation Leo.

Three planets gather in the predawn sky in early March. Of these, **Mars** is both the highest and the faintest, shining at magnitude 1.3. On March 1, Mars lies just below the waning crescent Moon. Saturn and Venus are to the Moon's lower left. Look again the following morning, and you'll find Venus, Saturn, and Mars all to the right of the Moon. On the morning of March 6, Mars passes just 0.4° south of Saturn. Make a point to contrast the ruddy hue of Mars with Saturn's soft golden color. This conjunction is the closest these two planets will be to each other until the next century.

Late last month **Saturn** emerged from out of the Sun's blinding glare. This month it appears more conspicuous among the background stars of Capricornus, where it shines at magnitude 0.8. After passing Mars on March 6, Saturn becomes the highest of the three planets visible before dawn. In late March, the trio stretches out along the ecliptic shortly before twilight begins. The crescent Moon sweeps through the area again around month's end. It extends the line of planets on March 28, passes near Saturn on March 29, and lies near Mars on March 30 and 31.

Venus doesn't do much this month except shine brilliantly — low in the east-southeast shortly before dawn — but that's enough. At magnitude –3.9, Venus is by far the brightest object in the sky with the exception of the Sun and Moon. It forms an anchor for Mars and Saturn, the two other morning planets, as they pass each other and

THREE PLANETS CLUSTER low in the southeast on mornings in early March. But your best view comes half an hour before sunrise on the 1st, when a slender crescent Moon joins the scene.



then inch higher in the east. On the last day of March, the Moon is near Mars, but it's also poised to pass near Venus the following morning.

THE STARRY SKY

Before the bright stars of winter disappear for another season, look to the south during the evening hours for Procyon, the brightest star in the constellation Canis Minor, the Lesser Dog. At magnitude 0.4, Procyon ranks as the 8th-brightest star in the sky. Yet despite Procyon's brilliance, Canis Minor is pretty unspectacular. Most people see only two stars in this constellation, the other being a 3rd-magnitude star located just over 4° from Procyon.

Procyon is most famous as one of the two Dog Stars. The other is brilliant Sirius in the nearby constellation Canis Major. Many stories have both Canis Major and Canis Minor as belonging to the great hunter Orion. However, other stories assign different masters to the dogs. Some say they belong to Diana, goddess of the Moon, who was known for her love of the chase.

Like the sibling of a celebrity, Procyon is known mainly for its association with Sirius. The star's Latin name is *Antecanis* or "before the dog," a reference to the fact that Procyon rises about 20 minutes before Sirius. The rising of Sirius before the dawn was an important event to the early Egyptians, because it foretold the yearly flooding of the Nile. The appearance of Procyon was a signal to the early sky watchers that Sirius would soon appear.

Procyon and Sirius lie on opposite sides of the faint winter Milky Way. An Arabian legend describes two sisters journeying across the sky. When they came to the great Sky River, the older and stronger sister, Sirius, plunged in and swam across. Meanwhile the younger and weaker sister, Procyon, remained weeping on the river's northern bank — where we see her today.

At a distance of approximately 11 light-years, Procyon is one of the nearest stars. In 1718 Edmond Halley noted that the stars Procyon, Sirius, and Arcturus had changed positions since they were recorded in the ancient Greek star catalogs. Halley made an enormous intellectual leap to suggest that this motion was due to the actual motions of the stars through space, a notion new to astronomers then. Now such changes in stars' positions on the sky are observed routinely. They're known as "proper motions," a staid name to describe an idea so fantastic as that of stars hurtling at many miles per second through space.

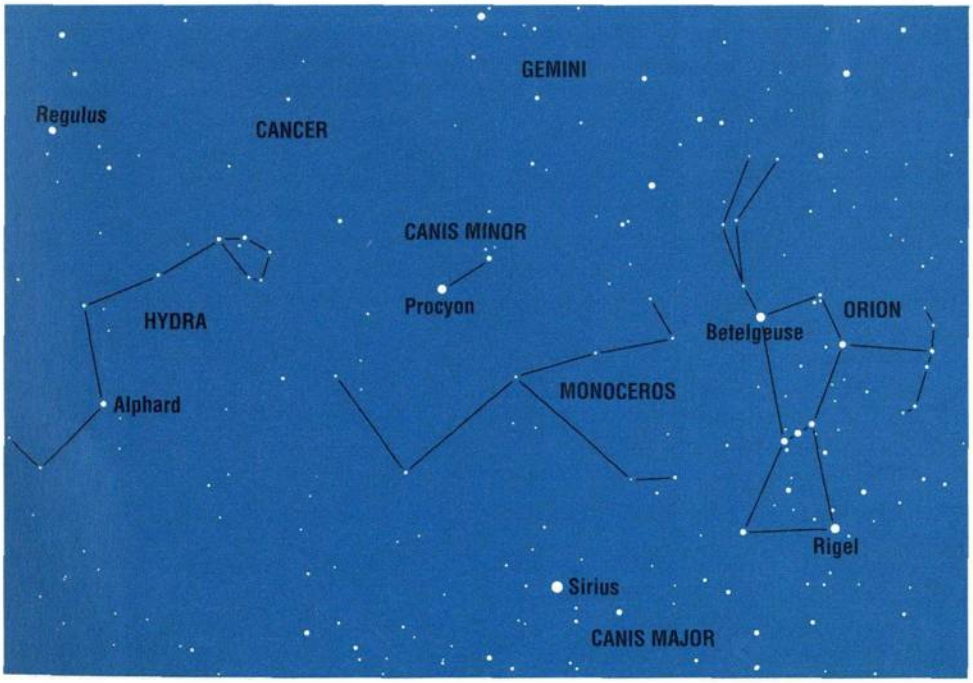
Very careful measurements show that Procyon does not follow a straight path. It "wobbles" in a way that allowed astronomers over a century ago to deduce that Procyon has a companion. That companion is a white dwarf now known as Procyon B. This incredible star packs a mass 65 percent that of the Sun into a sphere only about twice the diameter of Earth! □

Deborah Byrd's new radio series, "Earth and Sky," can be heard on stations in the United States, Canada, and Guam.

DELAY IN MOONRISE
(expressed in minutes)

Latitude	March 18	Sept. 11
20°	60	34
25°	63	32
30°	66	30
35°	69	27
40°	73	25
45°	77	22
50°	81	18
55°	89	12
60°	97	7

The March Full Moon rises more than an hour later on successive evenings for most Northern Hemisphere observers, but the exact delay varies with latitude. This table lists the delay in moonrise from the night of the Full Moon to the next night in March and for the Full Moon coming in September (the Harvest Moon).



CANIS MINOR BOASTS the 8th-brightest star in the sky — 0.4-magnitude Procyon. The diminutive constellation can be found high in the south after darkness falls on any March evening.

Through the Eyepiece by Jeff Kanipe

THE SWINGING MOONS OF JUPITER

Unfortunately, observing the sky from the city gets a bad rap these days. The message is often "Don't bother. There's too much light pollution." This is true, of course, if you're looking for faint comets or deep-sky objects. Such pursuits require a sky free of the urban glow that can easily wash out extended objects in the eyepiece.

But you don't have to trek out to a dark sky to view the nearby planets. They're so bright they can be observed in a telescope just as well from an apartment balcony or rooftop in the heart of the city. Furthermore, planets do things; they exhibit phases, atmospheric storms, and shifting surface features. And in Jupiter's case there is an added bonus: the four Galilean moons, which continually do-si-do around the giant planet like square dancers. All you need is a small telescope to follow their ever-changing positions.

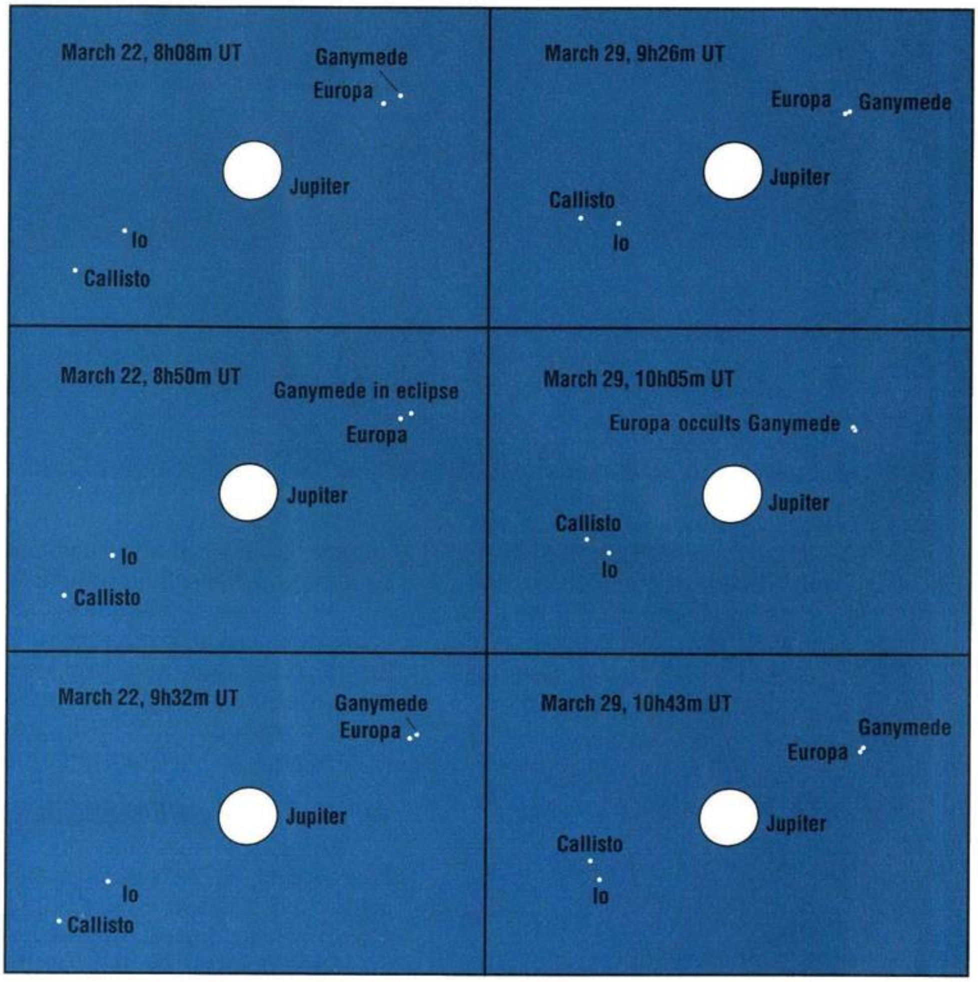
In March you have the chance to witness two of the last events in the ongoing series of Jovian mutual satellite events. The better of the two occurs on March 22, when Europa eclipses Ganymede. The eclipse begins at 8h08m universal time (UT) and runs until 9h32m UT (3:08 a.m. and 4:32 a.m. EST, respectively). Ganymede, Jupiter's largest and brightest moon, dims an easy-to-spot 36 percent at mid-eclipse. At that time the moon lies about three Jupiter-diameters east of the planet's center and Europa is slightly west of Ganymede.

The second satellite event — in this one Europa occults rather than eclipses Ganymede — occurs on March 29. Europa first intrudes on Ganymede's disk at 9h26m UT and finally separates from Ganymede at 10h43m UT (4:26 a.m. and 5:43 a.m. EST, respectively). The combined light of the two satellites drops by a perceptible 23 percent at maximum. Unfortunately for viewers on the East Coast, the approaching dawn drowns out the second half of the event. Observers farther west can witness the entire occultation.

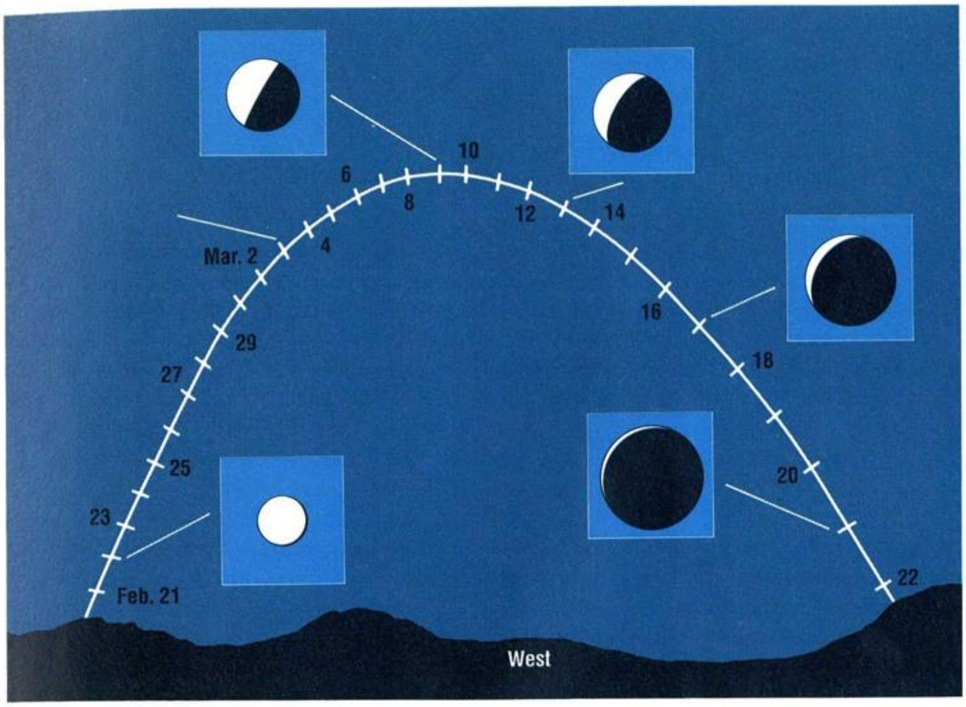
For optimal viewing of either event, you want the satellites to look like sharp points of light or, even better, tiny disks. How do you do this? If your telescope is a reflector, you can start by making sure it is well collimated. This is especially important if your telescope has a focal ratio of f/6 or less, though any reflector benefits from proper collimation.

Also, give your instrument time to adjust to the outside temperature. Because you'll be observing these mutual events in the wee hours, you might set your telescope in the garage or on a sheltered patio the night before, someplace that is out of the elements but where the optics can cool down to match the air temperature.

If possible, observe from a grassy area. A ground cover of some type helps insulate your observing site during the day and in turn


March 22, 8h08m UT
Ganymede
Europa
Jupiter
Io
Callisto
March 29, 9h26m UT
Europa
Ganymede
Jupiter
Callisto
Io
March 22, 8h50m UT
Ganymede in eclipse
Europa
Jupiter
Io
Callisto
March 29, 10h05m UT
Europa occults Ganymede
Jupiter
Callisto
Io
March 22, 9h32m UT
Ganymede
Europa
Jupiter
Io
Callisto
March 29, 10h43m UT
Ganymede
Europa
Jupiter
Callisto
Io

THE GALILEAN SATELLITES offer two mutual events this month — on March 22 Europa eclipses Ganymede and on March 29 Europa occults Ganymede. These diagrams show south at top to match the view in an inverting telescope.



MERCURY'S APPEARANCE EVOLVES DURING the course of its current evening apparition. The disk diagrams (shown with south at top) depict the planet's increasing angular diameter and waning phase.

releases heat slowly at night. Concrete and blacktop, on the other hand, radiate the heat absorbed during the day back into the sky, making the images of stars and planets shimmer violently.

Whatever type or size telescope you have, start observing with about 40x per inch of aperture. You'll want to "zoom in" on Europa and Ganymede, so experiment with higher magnifications, but don't go so high that the images begin to look like frying eggs. If you're intent on observing the subtle drop in light intensity, you might edge Jupiter just out of the field of view and so avoid its glare.

Jupiter itself was a fascinating object for study throughout late fall. The entire disk was banded with narrow gray and brown belts that seemed to change in intensity from week to week. The North Tropical Belt appeared darker than usual, and bluish festoons arced toward the equator from the still prominent North Equatorial Belt. As I wrote this in mid-November, the South Equatorial Belt was more of an ill-defined brown smear dominating the planet's southern hemisphere. In March, Jupiter reveals an apparent equatorial diameter of 44" and shines brightly at magnitude –2.5. The giant planet looms large and glorious in the telescope, presenting an ever-changing panoply of clouds, storms, and moons that can best be appreciated by an attentive eye.

MERCURY AT GREATEST ELONGATION

This month sees innermost Mercury putting in its best evening appearance of 1992. You can begin looking for the planet in late February, when it is somewhat brighter (at magnitude –1.2) than it is in March but lies lower in the sky. Mercury is at its best when it reaches greatest elongation — its greatest angular distance from the Sun as seen from Earth — on March 9. Then it lies 18° east of the Sun, which puts it 11° above the western horizon 30 minutes after sunset. Though still quite bright at magnitude –0.3, Mercury is low enough that you'll have to do a little work to see it.

Find an observing site with a clear horizon to the west — a ball park or tall knoll will do as long as there are no trees or buildings to block your view. Be sure to bring along a pair of binoculars. These will help you spot the planet long before you can see it with the naked eye. Then zero in on Mercury with your telescope and a moderate-power eyepiece.

I wish I could promise you craters, ice caps, or some other exotic surface features, but Mercury is immersed so deeply in Earth's atmospheric murk that a telescope will, at best, show only the phase and a kind of "Old Yeller" hue that doesn't suggest the real color of the planet. (Under good conditions, it looks almond-colored to me.) Nevertheless, watching Mercury's phase and apparent size change during the last week of February and the first half of March makes for a good observing project. In late February the innermost planet appears 5" across and shows a distinctly gibbous phase; by greatest elongation it grows to 7" in apparent diameter and appears just under half lit; and on March 17 it extends a full 9" across and displays a slender crescent just 14-percent lit.

GREAT RED SPOT TRANSIT TIMES

Date	Time
March 1	3:22 a.m.
March 1	11:13 p.m.
March 3	4:59 a.m.
March 4	12:51 a.m.
March 6	2:29 a.m.
March 8	4:07 a.m.
March 8	11:58 p.m.
March 11	1:36 a.m.
March 13	3:14 a.m.
March 13	11:05 p.m.
March 16	12:43 a.m.
March 18	2:21 a.m.
March 20	3:59 a.m.
March 20	11:50 p.m.
March 23	1:29 a.m.
March 25	3:07 a.m.
March 25	10:58 p.m.
March 28	12:36 a.m.
March 30	2:14 a.m.

The Red Spot on Jupiter can be seen for two to three hours before and after the transit times listed. All times are EST; subtract 1 hour to convert to CST, 2 hours for MST, and 3 hours for PST.

VESTA AT OPPOSITION

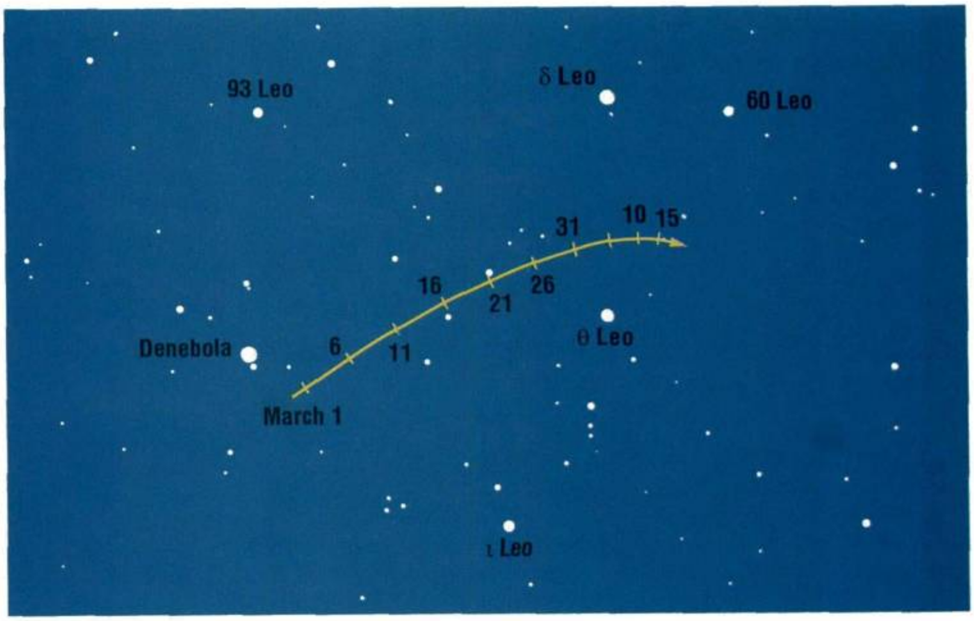
Now rising in the east at sunset is the familiar sickle-shaped asterism that forms the head of Leo the Lion. To the sickle's east, the lion's triangular hindquarters, marked at its easternmost apex by 2nd-magnitude Denebola, literally brings up the rear. Around the middle of March, if you are lucky enough to observe under a truly dark sky, your naked eye might catch the glint of a 6th-magnitude "star" lying about 3° due west of Denebola. You'll have no trouble spotting it in binoculars. Yet despite its brightness, you won't find this object on any star chart.

This is Vesta, the third largest of the big four asteroids and the brightest of all asteroids in our solar system. It is brightest at opposition on the night of March 8/9, when it reaches a peak magnitude of 5.9. And it remains quite bright throughout the month, easily visible in binoculars and telescopes, even from suburban locations.

If you've never seen an asteroid, now's the time to do so. This one couldn't be easier to locate. Use an eyepiece that yields about a 1.5° field of view. That should give you plenty of scanning room. Fortunately, the area just west of Denebola is devoid of bright stars and the asteroid is the brightest object in the region. Use the finder chart or table of coordinates at right to zero in on Vesta. Once you've found it, zoom in with higher power.

Of all the large asteroids, Vesta has the most puzzling features. According to spectroscopic observations, this asteroid, with a diameter of 538 kilometers (334 miles), is composed of basaltic rock, material similar to that on the plains of the Moon. Astronomers still haven't figured out how that's possible or why few other asteroids share this characteristic. Additionally, Vesta has a high albedo, or reflectivity, hence its high surface brightness. Vesta reflects about 30 percent of the sunlight that strikes it, compared with Ceres, the largest asteroid, which reflects only 6 percent. Vesta also rotates fairly rapidly — about once every 5.3 hours. Astronomers have noted that as the asteroid rotates, its colors change, meaning it has varied surface features. Maybe someday we'll fly by and take a look!

Like a determined flea, Vesta makes its way northwestward through Leo's hindquarters for the rest of March, ending up a little over 1° northeast of Theta Leonis on the 31st. At that time it is a still-respectable magnitude 6.3. This is a good time (and good part of the sky) to photograph the asteroid's trail relative to the stars. Load some quality black-and-white film (T-Max 100 or Tech Pan 2415) and mount your camera at the prime focus of your polar-aligned telescope. Center the field of view and expose for twenty or thirty minutes, being sure to guide carefully. Take several exposures of varying lengths. When developed, these photos should show Vesta's stubby telltale streak going its own way among the stars — a major minor planet marching to the beat of a different drum. □



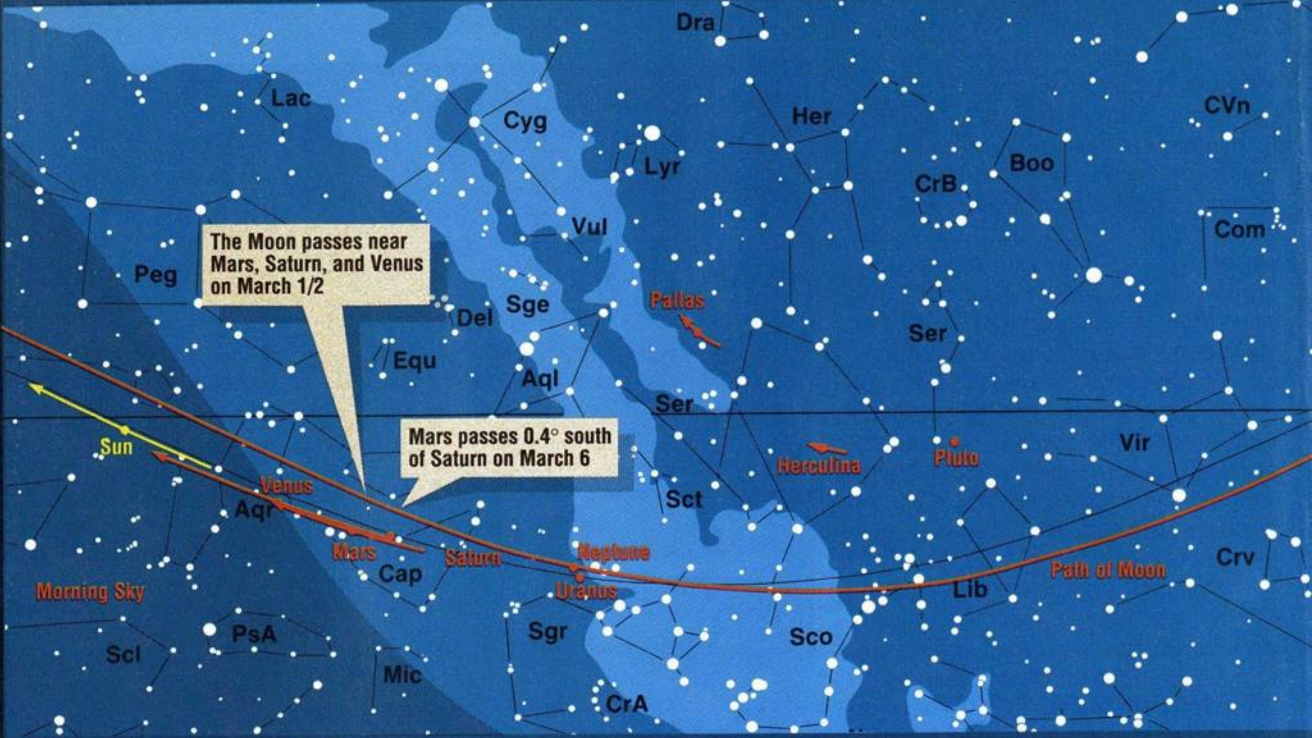
VESTA TRAVERSES the hindquarters of Leo the Lion, a distinctive asterism that makes spotting this 6th-magnitude asteroid particularly easy this month. Positions are shown for 11 p.m. EST (10 p.m. CST, 9 p.m. MST, and 8 p.m. PST).

COORDINATES FOR VESTA

Date	R.A. (2000)	Dec.
March 1	11h43.8m	13°44'
March 6	11h39.4m	14°26'
March 11	11h34.8m	15°05'
March 16	11h30.1m	15°40'
March 21	11h25.6m	16°11'
March 26	11h21.3m	16°36'
March 31	11h17.4m	16°54'
April 5	11h14.0m	17°06'
April 10	11h11.3m	17°11'
April 15	11h09.3m	17°09'

A former associate editor of ASTRONOMY, Jeff Kanipe is the editor of Star Date *magazine, which is published by McDonald Observatory at the University of Texas at Austin.*

The Solar System March 1992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Vir
Herculina
Pluto
Venus
Sct
Aqr
Mars
Saturn
Neptune
Cap
Crv
Path of Moon
Morning Sky
Uranus
Lib
Sgr
PsA
Sco
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Mic
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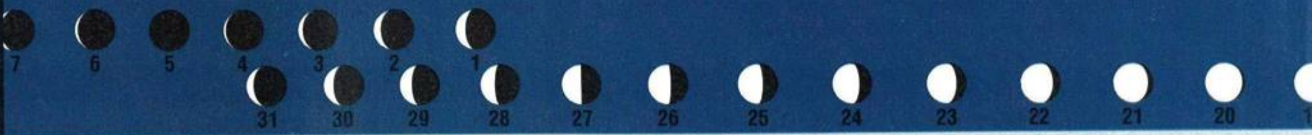
The Moon passes near Mars, Saturn, and Venus on March 1/2

Mars passes 0.4° south of Saturn on March 6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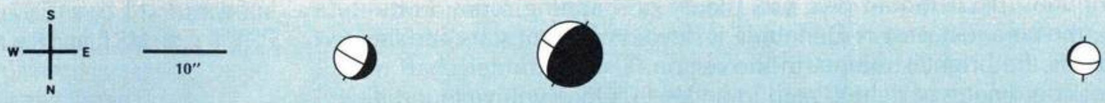
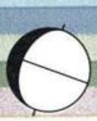
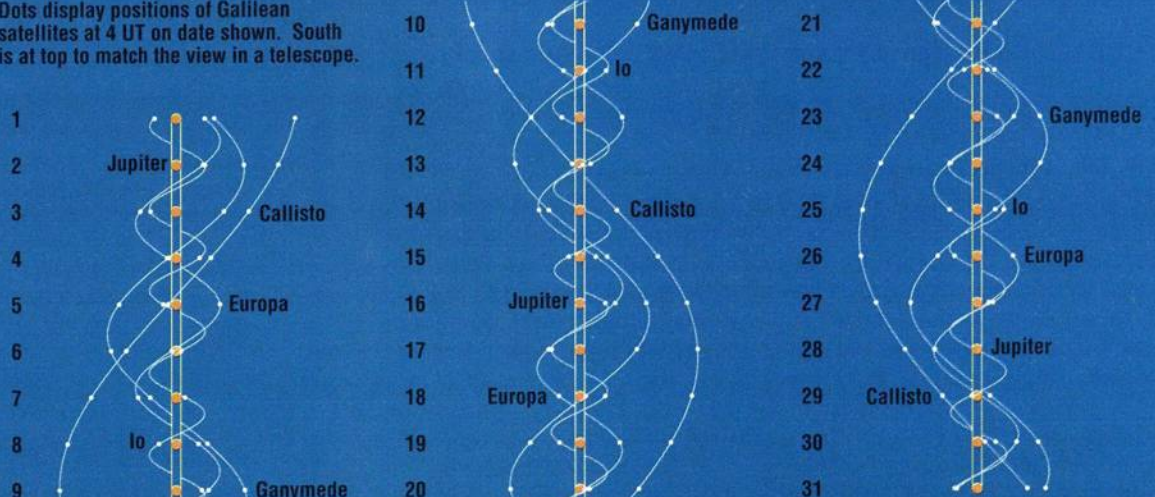


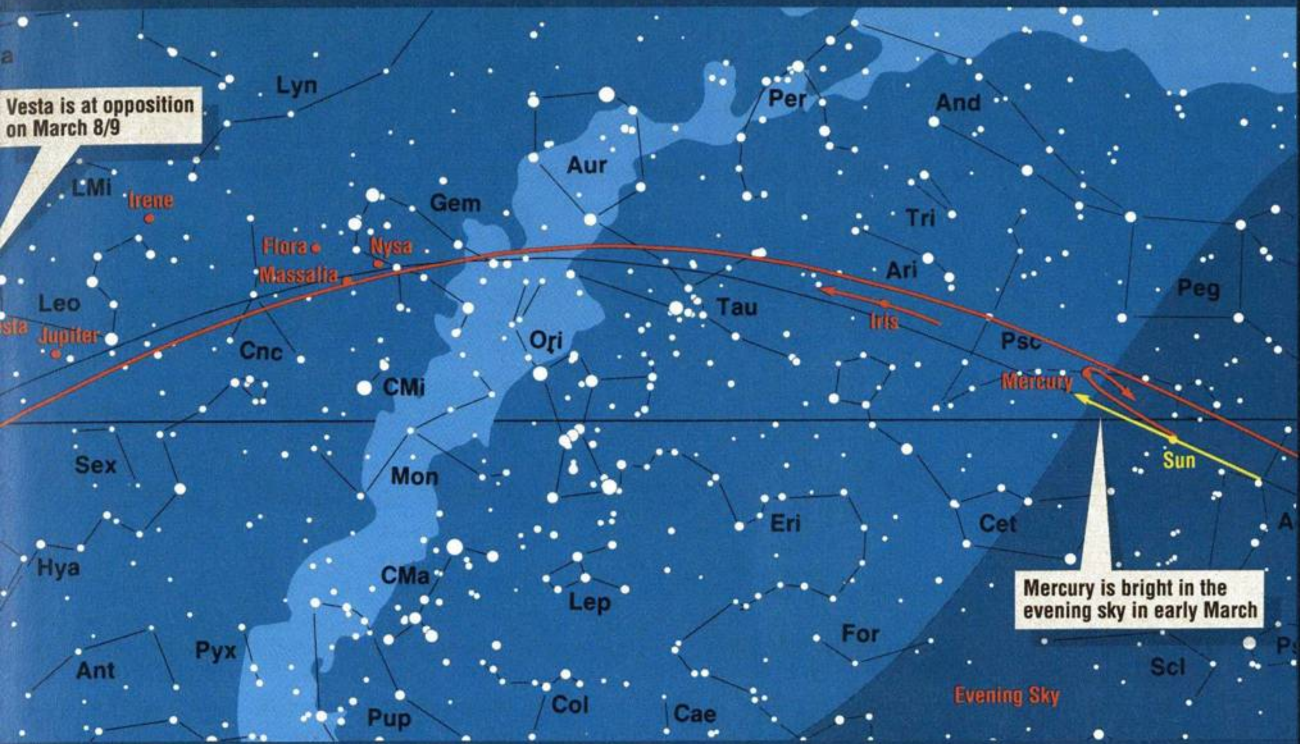


Planet	MERCURY	MERCURY	VENUS	MARS
Date	March 1	March 15	March 15	March 15
Magnitude	–1.1	+0.8	–3.9	+1.2
Angular Size	5.8"	8.6"	11.0"	4.4"
Illumination	81%	24%	92%	96%
Distance (AU) from Earth	1.151	0.781	1.524	2.106
Distance (AU) from Sun	0.315	0.332	0.728	1.409
Right Ascension (2000.0)	23h42.8m	0h36.3m	22h15.1m	21h31.0m
Declination (2000.0)	–1°53'	7°08'	–12°00'	–15°54'

Jupiter's Moons

Dots display positions of Galilean satellites at 4 UT on date shown. South is at top to match the view in a telescope.

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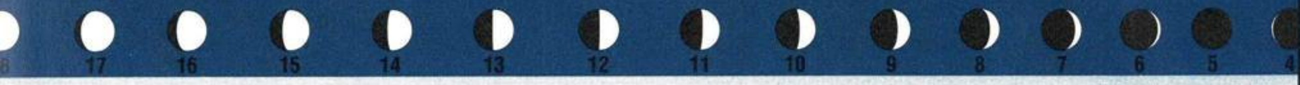
Vesta is at opposition on March 8/9

Mercury is bright in the evening sky in early March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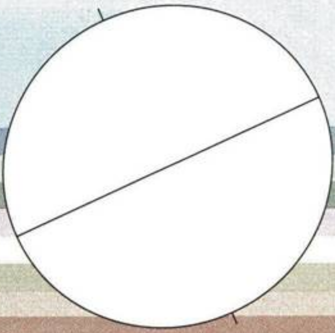
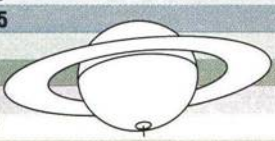
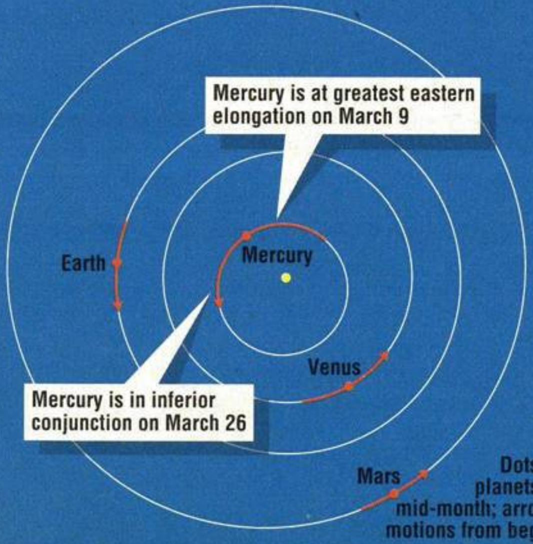



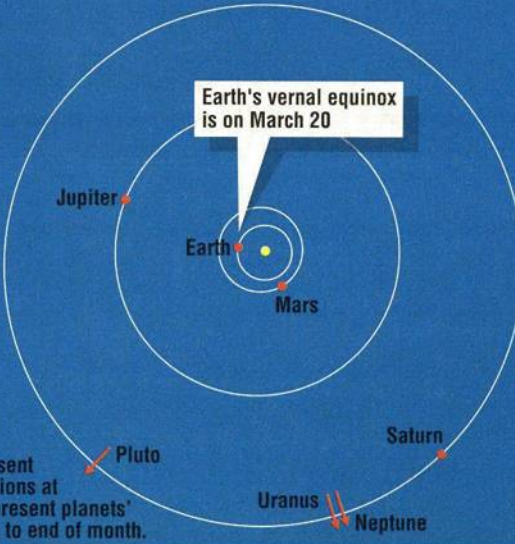
JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
March 15	March 15	March 15	March 15	March 15
−2.5	+0.8	+5.8	+8.0	+13.7
44.3"	15.5"	3.5"	2.2"	0.1"
100%	100%	100%	100%	100%
4.446	10.660	19.885	30.583	29.174
5.405	9.923	19.522	30.193	29.693
10h40.2m	21h08.5m	19h16.2m	19h20.6m	15h37.3m
9°54'	−17°09'	−22°41'	−21°24'	−3°53'

The Planets in Their Orbits


Earth
Mercury
Venus
Mars

Mercury is at greatest eastern elongation on March 9

Mercury is in inferior conjunction on March 26


Jupiter
Earth
Mars
Pluto
Saturn
Uranus
Neptune

Earth's vernal equinox is on March 20

Dots represent planets' positions at mid-month; arrows represent planets' motions from beginning to end of month.

GOING DEEP FOR GALAXIES

The combined forces of automatic guiders, fine-grain films, and a creative choice of subjects produce dramatic backyard photos of galaxies.

by David J. Eicher

There's a quiet revolution going on among astrophotographers all over the world. Computerized technology and sophisticated films — coupled with advanced information on objects — are giving rise to a new level of quality in backyard astrophotography. The prints and slides coming across my desk demonstrate this every day. They remind me of the old cliche, "They look as good as professional observatory photos of a few years ago." That's something that a few years ago amateurs said with a mischievous smile; now it can be said with a straight face.

The recent jump in the quality of backyard astrophotos can be attributed to three factors. First, professional-quality equipment is more easily (and cheaply) available than ever. This includes telescopes with accurate drives, sturdy mounts, and good optics, and cameras with hassle-free accessories that allow for easy focusing and guiding. The high-grade equipment also includes superb, affordable automatic guiders, an increasingly popular accessory for ultra-dedicated photographers. These guiders take the work out of tracking a star and increase nightly productivity as they eliminate fatigue.

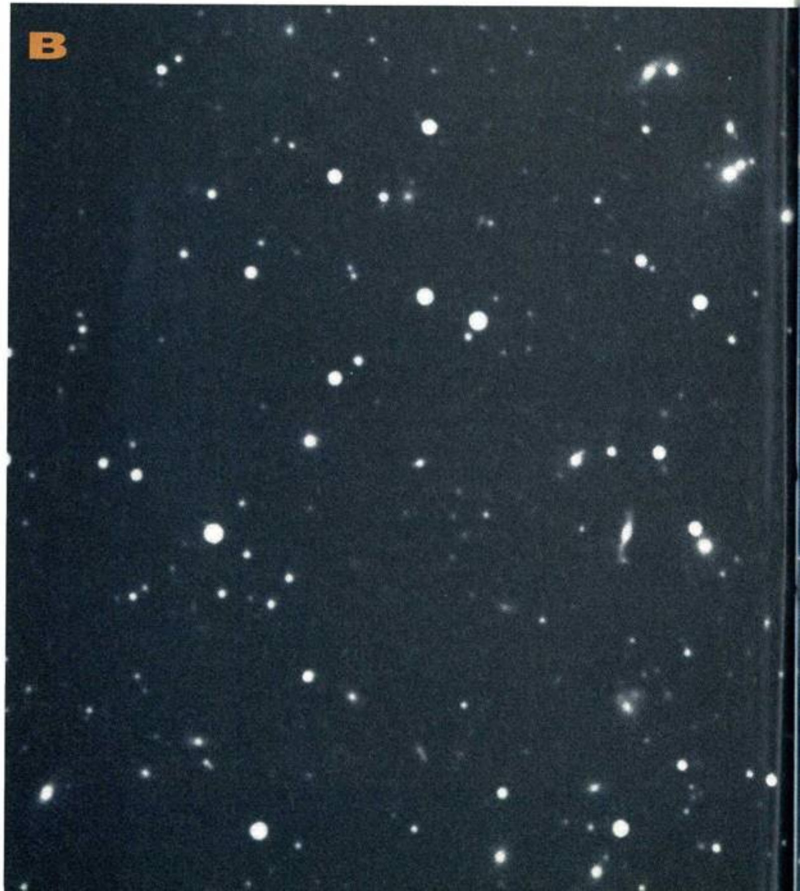
Second, ultra-fine-grain films are commonly available and astrophotographers have had plenty of time to experiment and nail down the correct exposure and developing times to maximize their results.

Third, the information explosion in deep-sky observing has provided the current generation of astrophotographers with the awareness of a new class of faint, challenging, mystifying, and downright sexy objects to photograph. Whereas a few years ago almost every backyard skyshooter recorded endless *Variations on a Portrait of the Orion Nebula*, now there seems to be a wider choice of interesting targets. Nowhere is this more the case than with galaxies.

Perhaps the most visible of the new generation of photographers are Tony Hallas and Daphne Mount of Oakview, California, a couple who do astrophotography as a way to relax. Hallas and Mount use a finely crafted, 6-inch f/7.5 apochromatic refractor for most of their photography. For color work — their specialty — they sing the praises of Fujicolor Super HG 400 film, hypersensitized in forming gas. Their exposures generally range from 30 minutes to more than 90 minutes long. Hallas and Mount have mounted their scope on a massive 12" Schaefer platform and employ an 80mm guidescope for finding the field. Until recently they guided with the 80mm instrument, but now they let electronics handle the guiding. Last year the couple bought an ST-4 automatic guider from the Santa Barbara Instrument Group, giving them time back from

A. DELICATE SPIRAL ARMS wrap tightly around the hub of M81, a showpiece galaxy in Ursa Major. Photo by Tony Hallas and Daphne Mount.

B. DISTANT GALAXIES PEPPER the field in this image of Abell 2151, the Hercules Galaxy cluster. Photo by Martin C. Germano.



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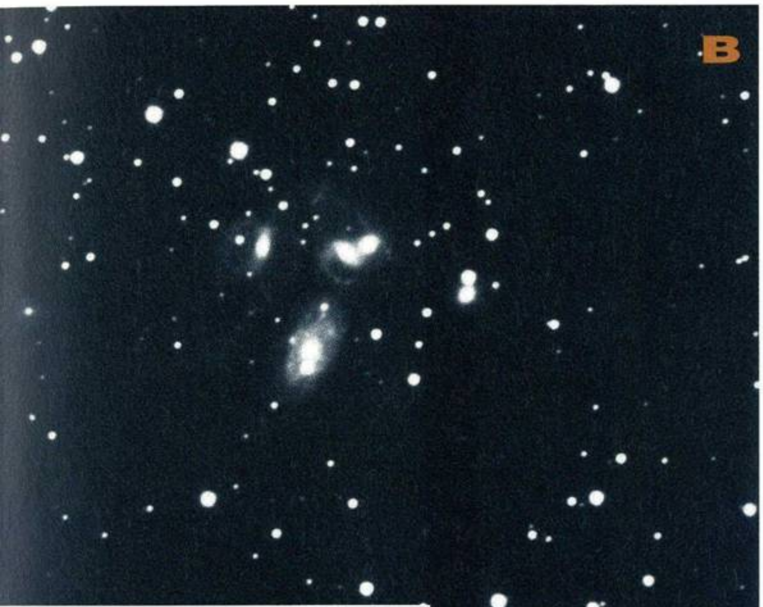
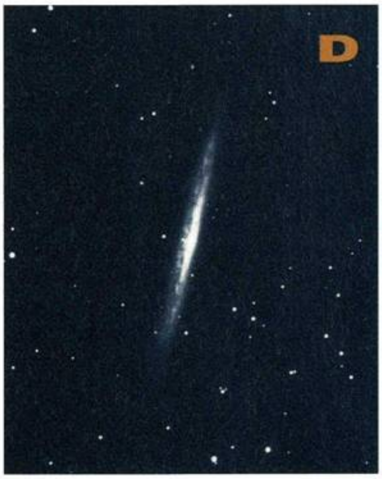
A. RESOLVED INTO STARS, the faint dwarf elliptical galaxy Leo I basks in the brilliance of Regulus. Photo by Chris Schur.

B. THE TANGLE OF GALAXIES dubbed Stephan's Quintet reveals evidence of galaxy interaction in this long exposure. Photo by Kim Zussman.

C. BRIGHT GALAXY M33 is a challenge for large-scope observers but is clearly visible in a deep exposure. Photo by Tony Hallas and Daphne Mount.

D. A SHIMMERING NEEDLE of light, edge-on galaxy NGC 5907 in Draco offers a razor-thin equatorial dust lane and arms that thin to invisibility. Photo by Chris Schur.





guiding to do visual observing as the telescope and camera guide themselves.

Galaxies are favorite targets because, as Hallas remarks, "It's a wonderful feeling to capture on film the beauty of blue star clouds and yellowish galactic centers." The photographs dramatically bear him out. They span a range from relatively bright objects like M33, M81, and M101, to challenging targets like the distant cluster of galaxies in Coma Berenices and the exotic NGC 3190 galaxy group in Leo.

Hallas and Mount "go deep" for galaxies in two ways. On bright objects they employ long exposures that record in striking colors tiny features in the galaxies. In M33, for example, the tiny nucleus is surrounded by clumps of blue-white star clouds in the galaxy's spiral arms. They capture the bright galaxy M81 and its faint spiral arms and wispy dust lanes. The delicate pinwheel structure of the galaxy M101 appears in a Hallas and Mount photo, complete with the galaxy's condensed nucleus and patchy blobs of stars and gas. By showing light collected over a long period, these photos reveal the subtle nature of familiar objects. A deep exposure brings out a hidden character in these impressive island universes.

A second way to go deep is to photograph distant, mysterious objects. In doing so astrophotographers don't get the kind of marvelous detail they would with bright objects, but they record fleeting glimpses of objects that are unimaginably remote. For example, the couple recently photographed the NGC 3190 galaxy group, a smattering of gravity-bound galaxies in the constellation Leo. This little group lies about 50 million light-years away, some three times more distant than M101. The primary galaxy is NGC 3190 itself, an edge-on spiral with a broad dust lane visible in the photo. The elliptical galaxy NGC 3193 lies just northeast of NGC 3190, near a 9th-magnitude star. Southwest of NGC 3190 lies the barred spiral NGC 3185, and northwest lies the faint, edge-on galaxy NGC 3187. Each of these remarkable objects shows clearly in the final photo, which brings us a little closer to a remote part of the universe. To take matters to the extreme, Hallas and Mount tackled the very distant Coma Cluster of Galaxies (distance = 300 million light-years) in another long exposure. At first glance this photo appears to be mostly empty, but a close inspection shows a cloud of faint wisps of light. Each of these distant patches of fuzz is an enormous galaxy, the two brightest being NGC 4889 and NGC 4874, supergiant ellipticals. Although they appear subtle and pastel-like in the photo, these galaxies are enormous monsters that would dwarf normal spirals like M101 or our own Milky Way.

A

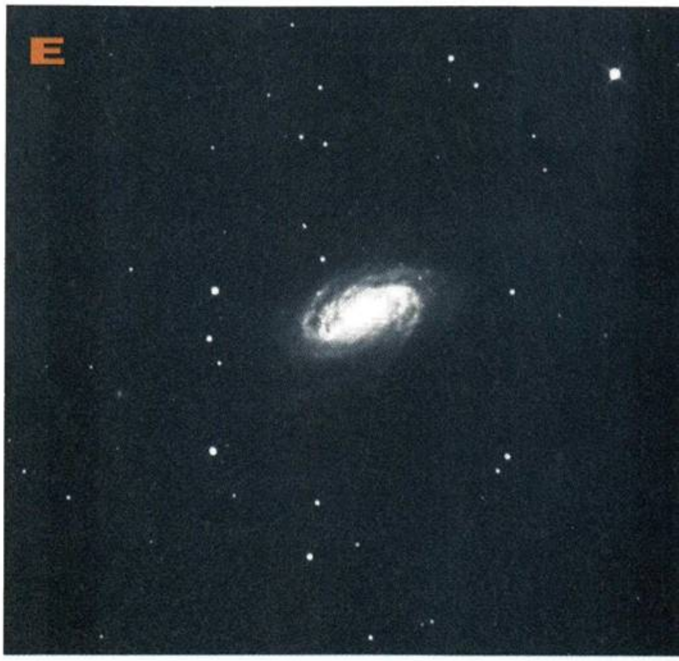
A. A REMOTE ZOO of galaxy types, Leo's NGC 3190 galaxy group serves up spirals, ellipticals, and lenticulars. Photo by Tony Hallas and Daphne Mount.

B. A DISTANT SPRINKLING of fuzzy patches, the Coma Galaxy cluster challenges the largest backyard telescopes. Photo by Tony Hallas and Daphne Mount.

C. A WARPED DISK of faint gas is visible on the perimeter of the dusty edge-on galaxy NGC 3628 in Leo. Photo by Chris Schur.

D. GIANT CLUMPS of gas and stars are visible in the spiral arms of galaxy M90. Photo by Kim Zussman.

E. FAINT EXTENSIONS of NGC 2903's spiral arms can be traced out from the main body of the galaxy. Photo by Chris Schur.



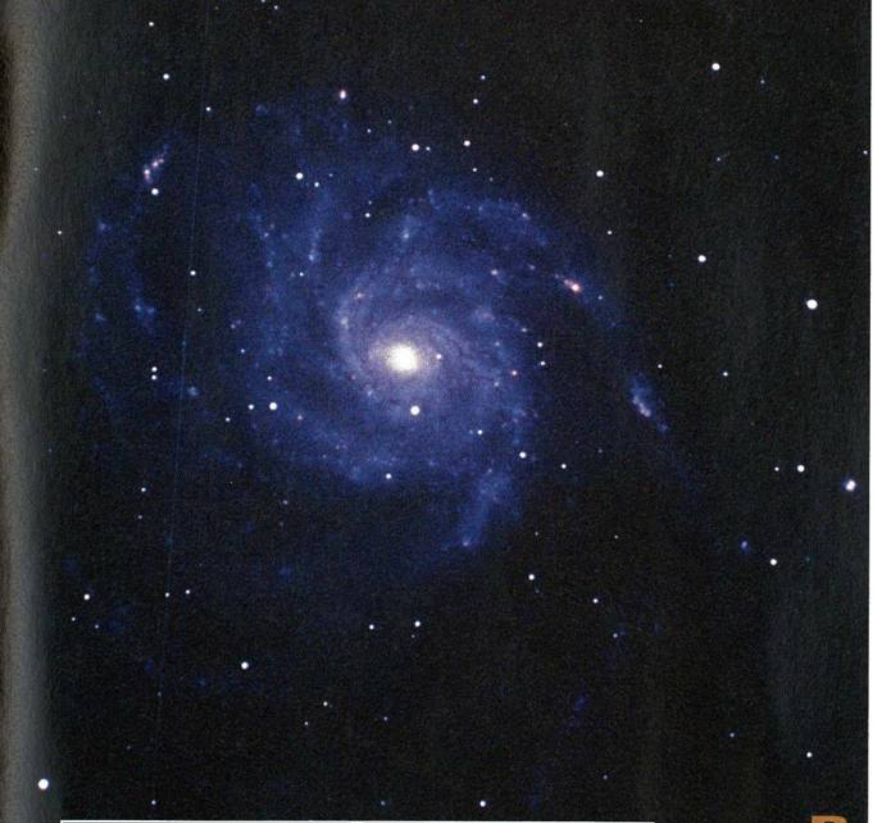
Another active astrophotographer based in southern California is Kim Zussman, a periodontist by profession who lives in Thousand Oaks and enjoys producing high-resolution black-and-white photos. Zussman uses a long-focal length system — a 14.5-inch f/8 Cassegrain scope — and ultra-fine-grain Tech Pan film to achieve a large image scale and extraordinary detail. He also goes deep on exposures, which range from an hour to three hours long. The results are superb: a look at Zussman's M90 photo reveals detail formerly visible only in professional observatory images. The galaxy's nuclear region is bright and oval and is surrounded by a smooth series of spiral arms containing bands of obscuring dust. Patches of bright nebulosity are visible along the arms in and around the galaxy's center.

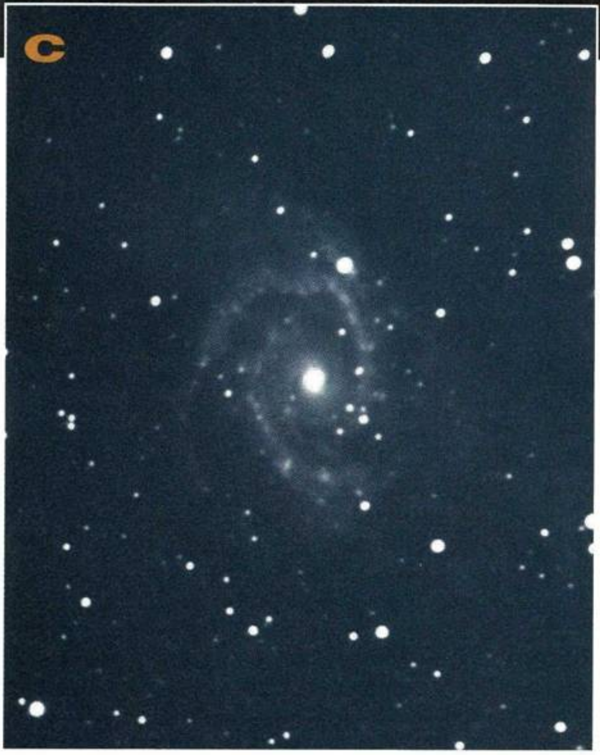
M90 lies in the Virgo Cluster at a distance of about 40 million light-years; Zussman's portrait of Stephan's Quintet, a small group of galaxies, carries us out an additional 220 million light-years. The galaxies in this group appear to be interacting, attached by faint loops of material visible in Zussman's photo. Yet the galaxies' redshifts indicate that they lie at different distances, so Stephan's Quintet offers a puzzle for cosmologists.

Zussman's technique for deep photography also brings us a closeup picture of a galaxy close to home — Barnard's Galaxy (NGC 6822) in Sagittarius. This dwarf galaxy lies within our Local Group at a comfortable distance of 2.0 million light-years, yet it is so faint that most backyard photos show it as merely a smudge. Zussman's image resolves the irregular galaxy into pinpoint stars, a stunning achievement.

Others have joined the deep-exposure fold. Martin C. Germano, a postal worker in Thousand Oaks, California, has amassed a collection of his own portraits of faint galaxies. Germano has used a variety of instruments for more than 15 years to record the faint light from spirals and ellipticals, single galaxies, and clusters. Chris Schur, an engineer living in the Arizona desert, has produced his own stunning collection of deep galaxy shots. And amateur astronomer George Greaney of Las Vegas has taken advantage of the Nevada desert to begin his collection of faint galaxy portraits.

These now classic portraits of galaxies light the way for the future of amateur astrophotography. In an era when CCDs seem to be grabbing much of the spotlight and in some minds threatening the existence of good old astrophotography, these photographers have demonstrated that despite new technologies, capturing photons on film still shows much promise. So that we can see elements of detail in bright, nearby galaxies and venture into the universe to the depths of the exotic monsters, skilled astrophotographers will continue to provide for us intimate views of the realm of the galaxies. ☐





A. THE BRIGHTEST STARS in the nearby dwarf galaxy NGC 6822 can be seen in this deep exposure. Photo by Kim Zussman.
B. M101 IN URSA MAJOR appears as a bright pinwheel in a long-exposure image. Photo by Tony Hallas and Daphne Mount.
C. A DEEP EXPOSURE of galaxy NGC 2997 brings out the asymmetrical shape of the galaxy's arms. Photo by George Greaney.

6 Steps to Better Astro-Prints

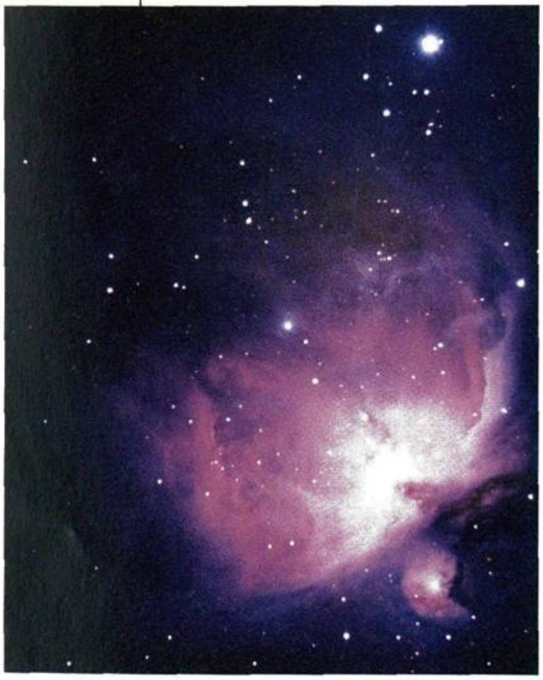
Want your darkroom time to be rewarding and fun? Here are six simple things you can do to get more out of astrophotography.

by Larry Myers

1 Take your time — don't rush it.

This is obvious advice. But it is astonishing how few astrophotographers follow it. If you've spent hours at the telescope collecting the photons on the film, why not devote a similar amount of time to making each print?

I think it's just as important to be mentally alert when making prints as it is when exposing film at the telescope. So my normal procedure is to develop my film the morning after shooting the pictures, but not to make prints. They take too much time and when you've been up all night, you're just too darn tired and impatient to do a good job anyway.



THE ORION NEBULA contains a huge range of brightness. Photos by author.

2 Carefully inspect your negatives.

Use a 5x to 10x magnifier, such as an eyepiece or a photographer's loupe, and consider buying or building a lightbox.

Be picky in choosing just which frames are good enough to spend your darkroom time on. High-magnification scrutiny can save you tons of time and frustration, not to mention paper and chemicals.

Pay close attention to the star images that are middling-to-faint in brightness. (These show focus or guiding errors better than the brightest stars do.) It takes a tack-sharp focus to capture the faintest stars and nebulae your equipment can get. Badly misfocused images look like donuts. But slightly out-of-focus images are trickier to detect. Watch for stars that appear soft or enlarged.

Next, check the guiding. Was it as good as you can do? Look for elongated star images and remember that every defect will be greatly magnified in the print. Is the film scratched? Ask at your photo store for scratch remover.

Never discard your negatives, however, even the bad ones. Who knows? You may have recorded a comet or supernova on one.

M13, THE GREAT GLOBULAR in Hercules, needs a burned-in core.

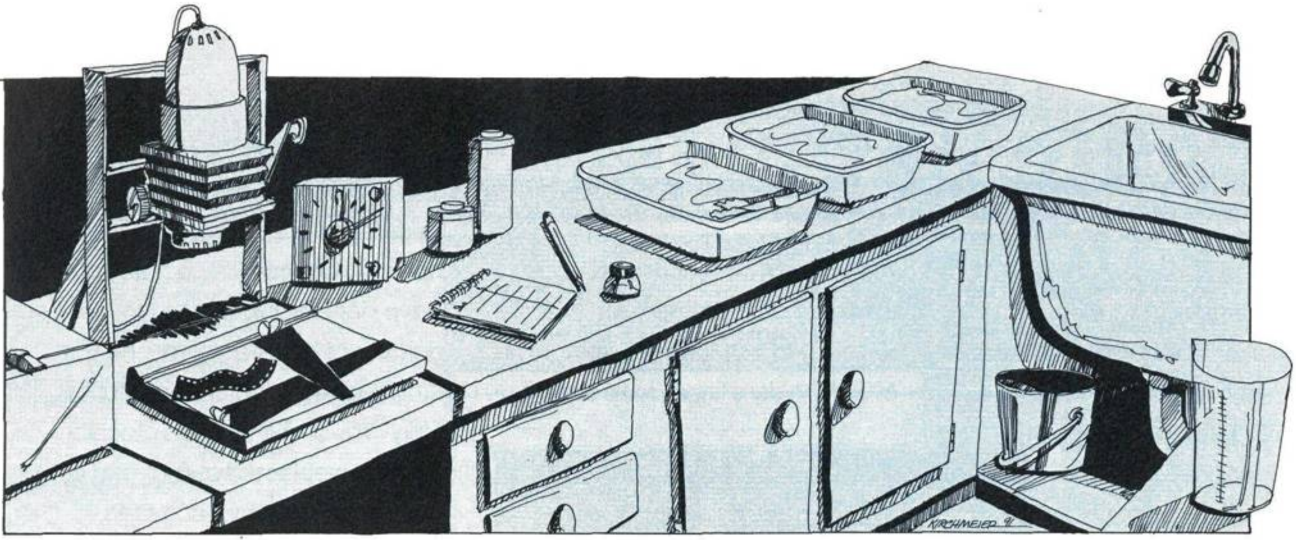
3 Plan, plan, plan.

After examining your negatives, make a list of the frames you wish to print and set the film strips aside. Determine how large each print will be. If you are printing in color, choose your starting filter combination.

Many photographers head for the darkroom with a vague urge to make prints. Of course the result is chaotic. I normally choose to print only one or two frames. By limiting the job, I feel less rushed and therefore do a better job. Pick similar astronomical subjects — a couple of galaxies, for example — so the filtration will be similar. It's a lot easier to go from one nebula to another than to hopscotch through different types of objects.

Setting realistic goals for a darkroom session is a good way to keep the inevitable confusion under control. Also, carrying out a simple plan is marvelously rewarding — the sense of accomplishment will be delightful.

THE DUMBBELL NEBULA in Vulpecula is small but relatively bright.



4 Keep a notebook.

If you do nothing else, do this. And protect it as you do your negatives.

Astrophotography is unlike taking cat-and-dog pictures. We do strange things to our film. We gas it, we chill it, we expose it longer than it was meant to be. We even develop it backward, turning slide film into negatives. Every variable can make film react in odd ways.

Record details about each print — the negative number, film type, color filter(s), paper-pack correction numbers, enlarger exposure time and f/stop, enlarger head height, and whether the negative was hypersensitized or chilled. Note how the print turned out.

This will save time in reprinting a negative — or even in making a first attempt at a new negative. And that goes double if much time passes between darkroom sessions.

5 Learn, learn, learn.

Amateur astrophotography is rapidly changing. You can do things today that were unheard of a decade ago and new techniques may appear anytime. Beware of getting stuck in a rut. If you call yourself a deep-sky photographer, have a go at the Moon and planets once in a while (or vice-versa). The change in subject matter and technique will offer new challenges to limber up your mental muscles.

Pointers on new ideas can come from magazine articles, photo captions, or friends and fellow members of an astronomy club. Clubs are ideal for sharing the collective wisdom. If you're a beginner, you'll learn lots by hanging around, listening, and asking questions. And if you're in a more advanced category — why not spread the experience and help get beginners going?

6 Cut loose; get creative.

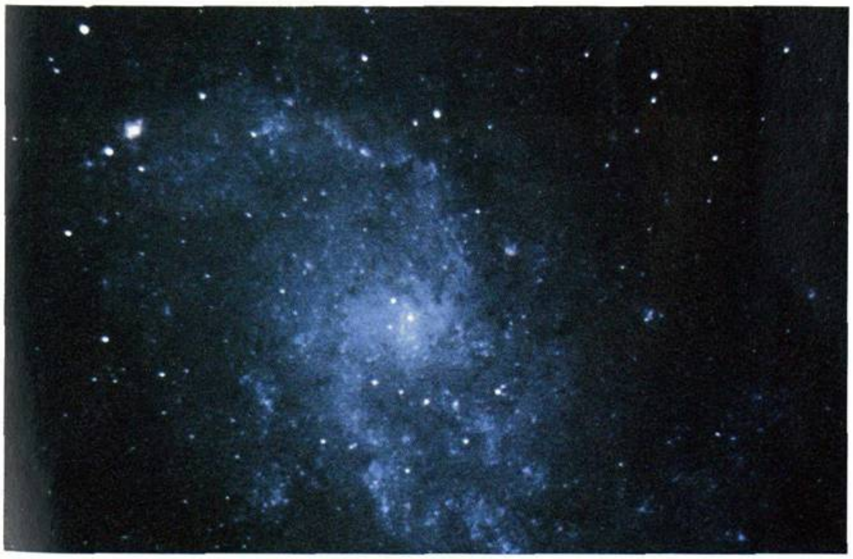
It takes coaxing to extract the wealth of info in your astronegatives. So get bold and break a few rules. All you have to lose is some print paper and time.

Astrophotography goes into photographic realms where extreme contrasts are normal, and skill-dependent techniques such as burning, dodging, and masking are routine tools for getting the most from balky subjects.

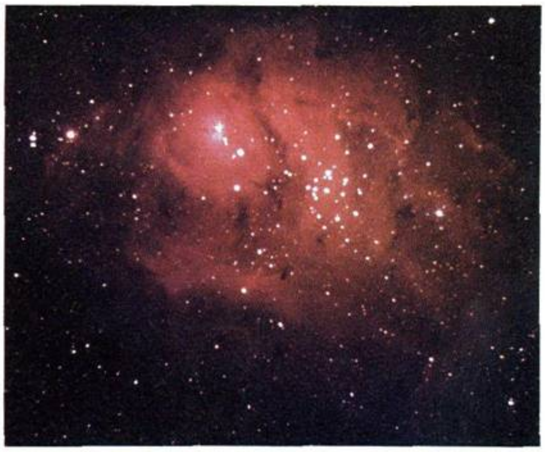
It's fun to haul out old negatives. They may be great or hopeless, but in either case, you'll see them anew. As your skills grow, you'll do a different and probably better job printing than you did before.

The satisfaction of making the best print possible from a negative is hard to top. And enjoying yourself in astronomy is what it's all about. ☐

Larry Myers is an astrophotographer in southern California. His last article was "Dodge and Burn" in the May 1991 issue.



NAKED-EYE VISIBLE, spiral galaxy M33 in Triangulum is a large but dim object that calls for enhanced contrast in printing.



THE LAGOON NEBULA, M8, in Sagittarius is bright and easy to photograph.

Peer deep into the cosmos from your backyard.

From the editors of ASTRONOMY

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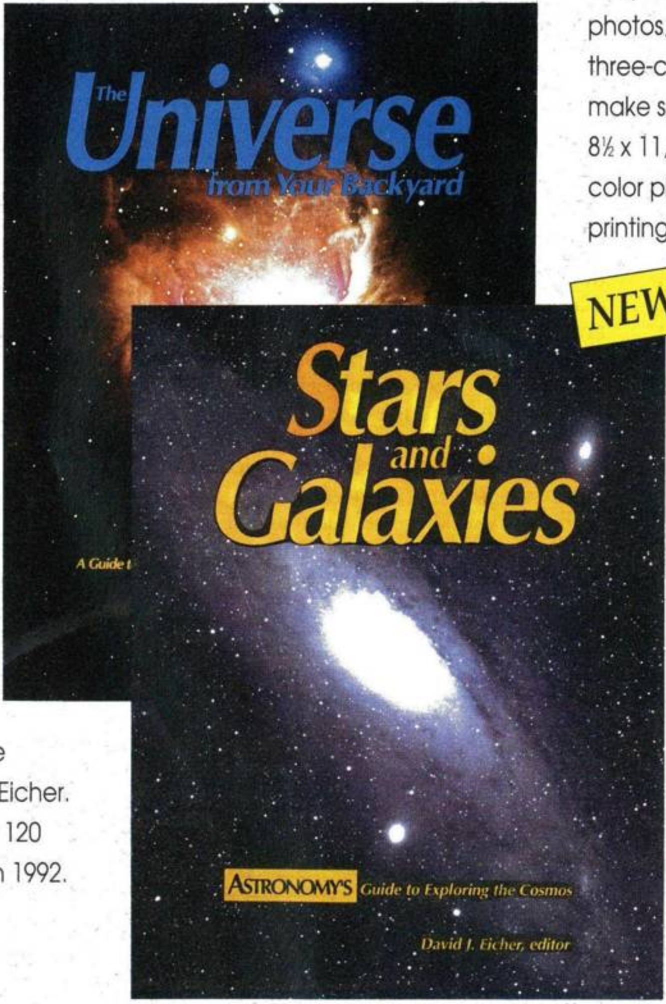
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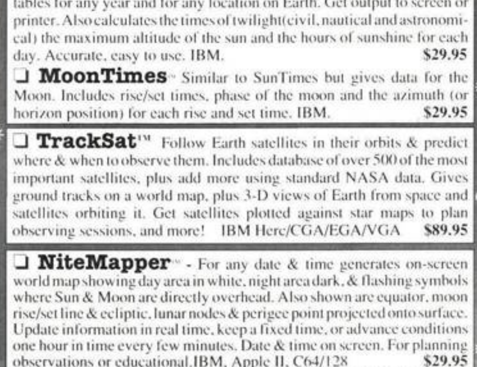

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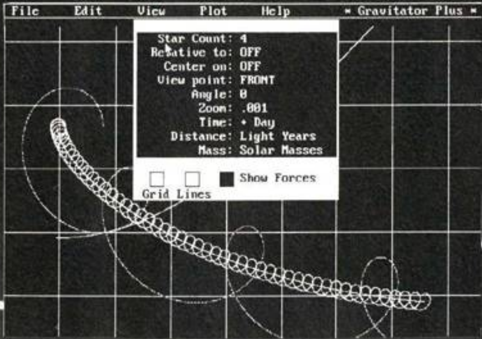

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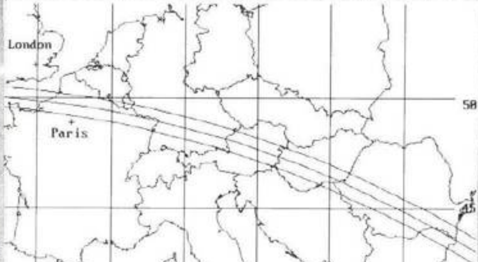

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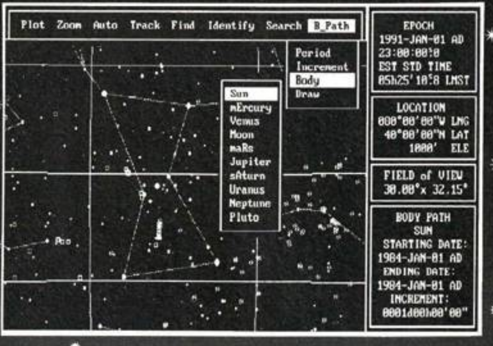

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1991-JAN-01 AD
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EST STD TIME
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LOCATION
000°00'00"W LNG
 40°00'00"N LAT
     1000'  ELE

FIELD of VIEW
30.00°x 32.15°

BODY PATH
SUN
STARTING DATE:
1984-JAN-01 AD
ENDING DATE:
1984-JAN-01 AD
INCREMENT:
0001d00h00'00"
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Partial Solar Eclipse
Magnitude: 0.170  Obscuration:   0.3%
LAST CONTACT
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<***    NGC 3034  Located at TARGET    ***>

NGC# ObjTyp Cst  Mag Type          Size   R
3034 Galaxy UMA  9.5 Am           11'x 5'

(CIRCUMPOLAR)   TT: 17h35'20.3   (CIRCUMPOLAR)
```

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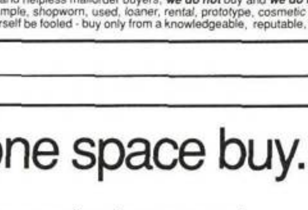

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HOW TO Clean Your Optics

Remove dust and dirt from your mirrors, lenses, and eyepieces. It'll make a big difference in what you see with them.

by Michael Porcellino

The most important thing you can do for your telescope is to keep its optics clean. Dirty, dusty optics scatter light, reducing the telescope's ability to deliver a clean image and producing images vastly degraded in contrast, sharpness, and detail. So few observers are aware of this or actually take the time to keep their optics clean that probably the majority of backyard observers are currently using telescopes that do not deliver the best images they are capable of.

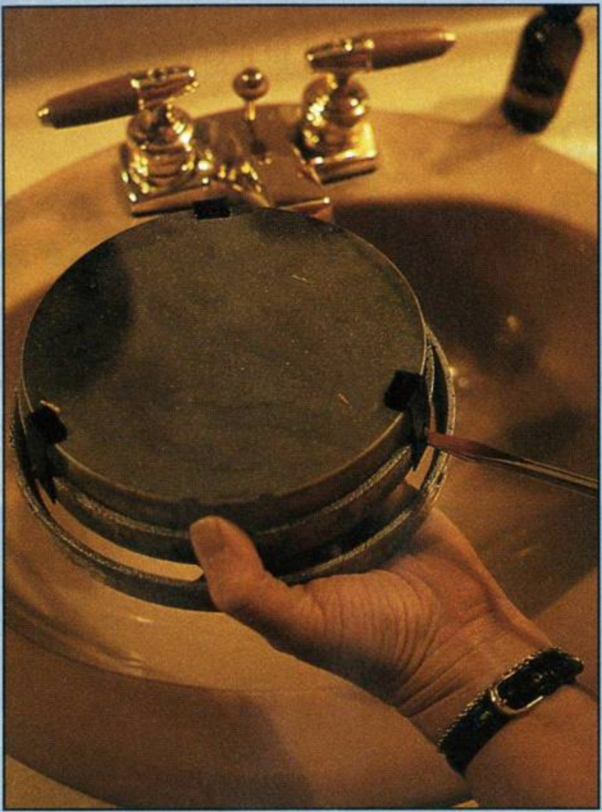
Think of it this way: Your telescope needs periodic maintenance to run at top operating condition. You clearly wouldn't drive your car for years without maintaining it, would you? Well, telescopes are a little like cars in that they need to be maintained too. The simple, straightforward task of cleaning your scope's optics is the best way to maintain your telescope in perfect operating order.

How to Clean Your Mirror

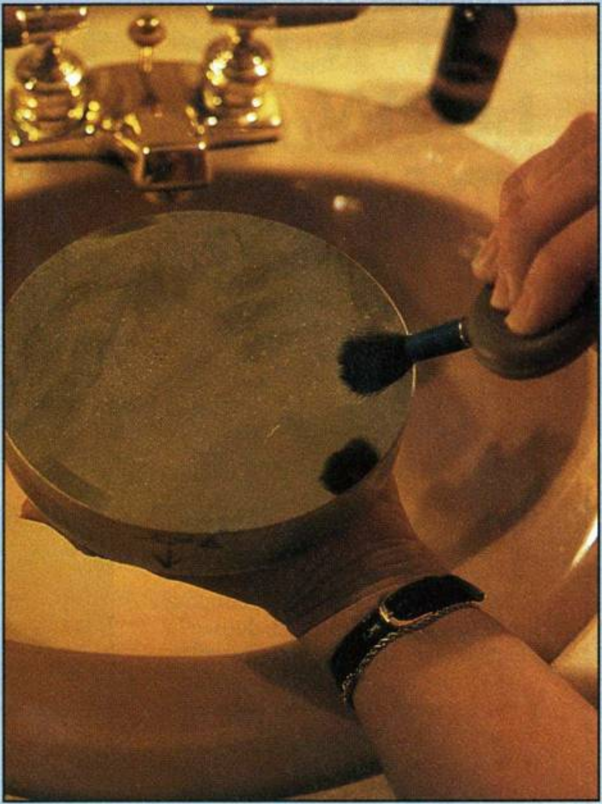
If you have a Newtonian reflector telescope, your job will be very simple. Two or three times per season, check your mirror to see that it is clean. If you can see an appreciable amount of dust on it, it's time to take the mirror out of the tube and clean it. You need not be excessive about this: don't clean the mirror every time you see a single speck of dust on it. In time you'll come to know when the mirror is dirty enough for a cleaning.

The first thing to do is remove the mirror. Unscrew the mirror cell and remove it from the telescope tube.

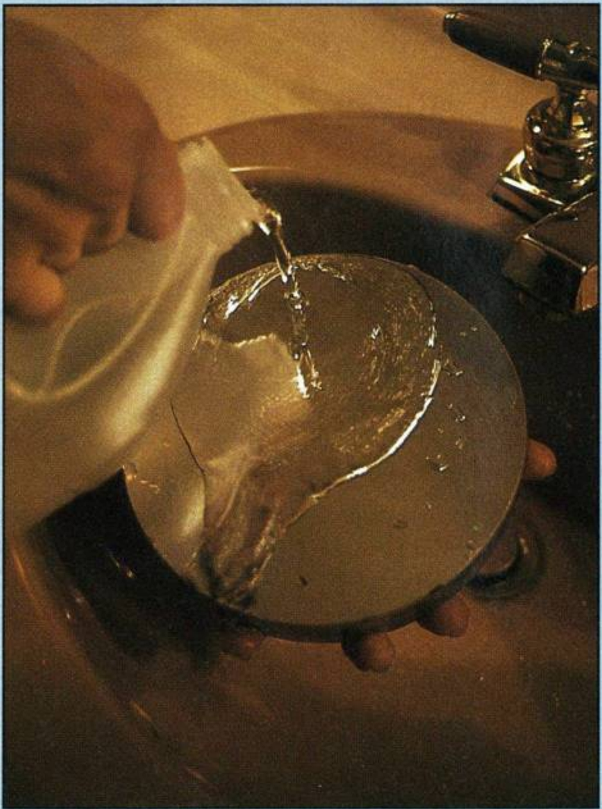
DIRT, DUST, AND FILTH cover a 6-inch mirror. Once cleaned, the mirror will scatter less light and will deliver clean, crisp, high-contrast images. Photo by Darla Gawelski.



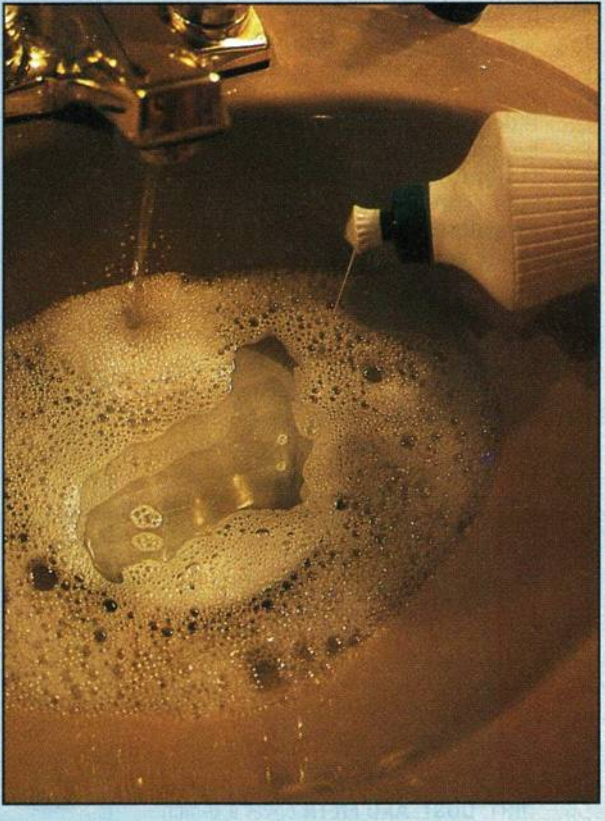
1. Remove the mirror from its cell, marking the first holding screw so the mirror can be placed back in its cell properly.



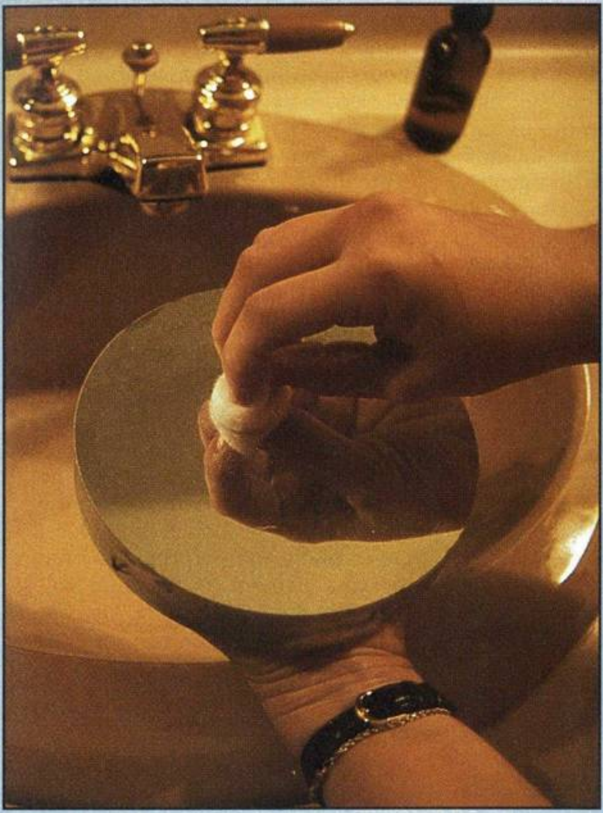
2. Blow off the gross dirt and dust by using a bulb or a can of compressed air like those used to clean camera lenses.



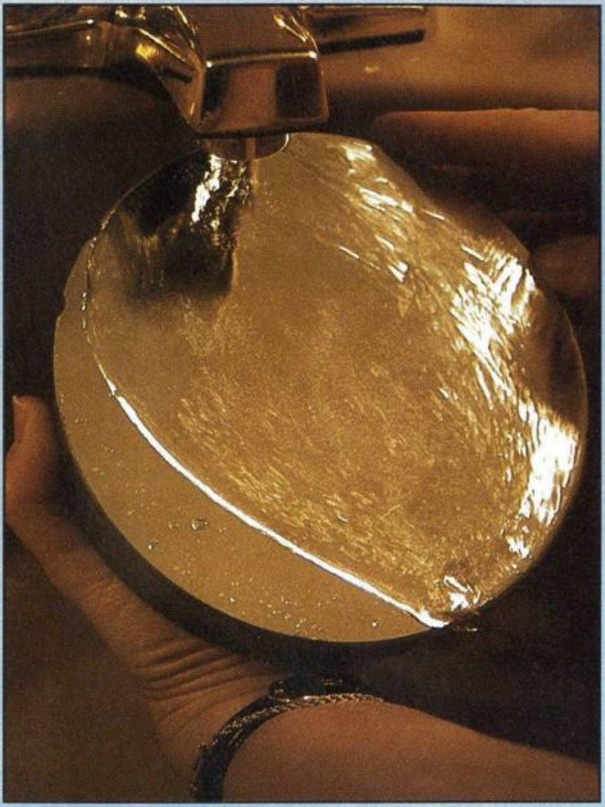
5. Rinse the mirror with a plentiful amount of distilled water.



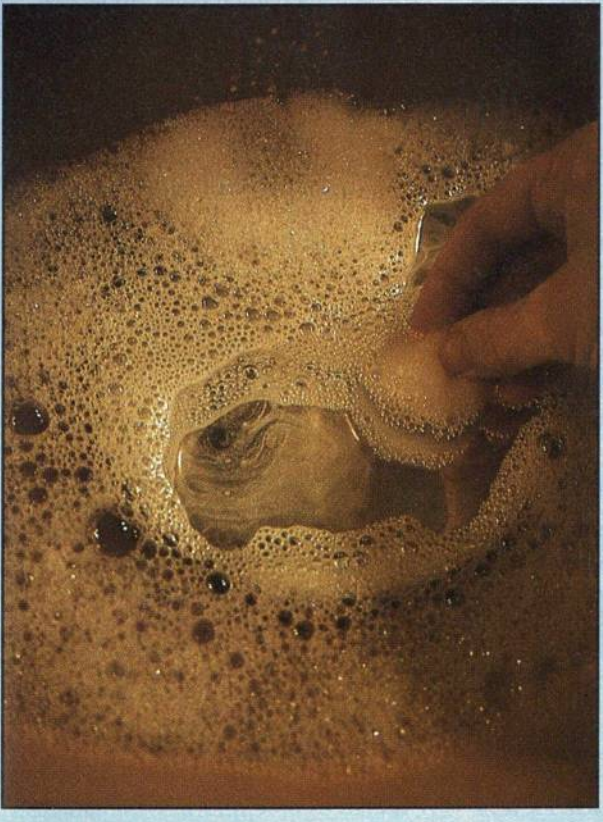
6. Fill the sink with water and a solution of detergent and let the mirror soak for several minutes.



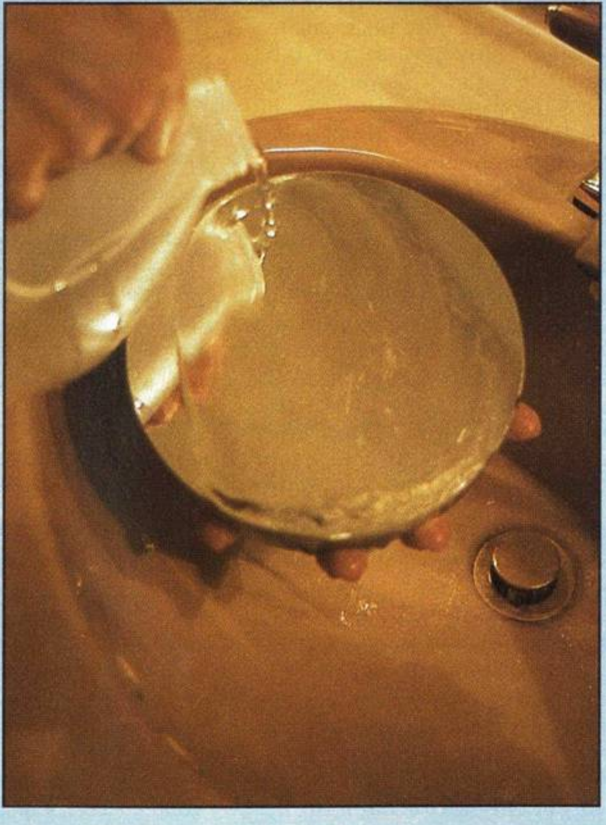
3. Use several balls of cotton to gently lift off remaining large dirt particles, but be careful not to scratch the mirror.



4. Wash the mirror by placing it on a towel in a sink and gently running room temperature water over the surface.



7. Gently stroke the mirror's surface with cotton balls as it rests underwater in the detergent solution.



8. Give the mirror a final rinse with distilled water and allow it to dry thoroughly. Photos by David J. Eicher.

Before you remove the mirror from its cell, however, mark the location of the screws that hold the mirror so that you can put the mirror back in with the same orientation. This will help you line up the clips and makes it easier to replace the mirror in the cell. Once you have this screw position marked, carefully unscrew the mirror clips and gently remove the mirror from the cell.

Carefully blow off any large particles of dirt that may have accumulated on the mirror surface. Either use a bulb from a camera cleaning kit or a can of compressed air like those sold for cleaning computer and camera parts. Do not use a brush of any kind, because the bristles can pick up the dirt and drag it around the mirror, creating microscopic scratches. Once you're convinced that the large stuff is gone, lightly saturate some soft cotton balls and very gently blot the surface to pick up other loose particles of dirt and dust. Be very careful because you are cleaning an extremely delicate surface. You are not actually cleaning the mirror's glass, but a thin coating on top of the glass. This aluminized coating is very soft and easily scratched.

Now it's time to move to the sink and roll up your sleeves! While you are at it, take off your rings, chains, and other loose jewelry because they could scratch the mirror surface. You'll need a couple of towels, some liquid detergent, distilled water, and cotton. First wash out and rinse the sink. Then place a folded towel in the bottom of the sink and rest the mirror on it face up. Run room temperature water over the mirror to loosen any remaining dirt on the surface. Then rinse the mirror in distilled water, remove it from the sink and let it dry standing on its edge (use another towel to keep it from slipping). Now go back over the surface blotting it with damp cotton to carefully remove any dirt.

Next, fill the sink with enough lukewarm water to completely cover the mirror and add a little liquid detergent — a teaspoon should do nicely. The detergent contains two-ended surfactant molecules that are attracted to water on one end and grease and dirt on the other. They will carry the dirt off the mirror just as they carry dirt off your clothes when you wash them. The next step is to put the mirror back on the towel in the sink and let it soak for a few minutes. After this soaking, swirl the mirror around as if you are panning for gold, but remember to keep the mirror completely underwater. This will wash any sizable dirt particles off the surface. Take a ball of cotton and, with the mirror still underwater, carefully swab the mirror surface. Use a constant, straight motion starting at one edge and gently moving across the mirror. Don't put any pressure on the cleaning stroke; just gently guide the cotton and let the weight of the cotton do the work. Discard the cotton after each pass. The next pass should overlap the first and so on until the mirror is completely clean.

Once you are finished you may want to go back over the mirror and clean the surface in a motion perpendicular to the first, but try this only if the mirror is still dirty. Drain the sink and run lukewarm water over the surface of the mirror for about a minute. Drain the sink again and give the mirror a good final rinse with plenty of distilled water. Distilled water prevents any impurities from remaining on the mirror.

LIST OF SUPPLIES

- √ Can of compressed air
- √ Cotton balls
- √ Distilled water
- √ Isopropyl alcohol
- √ Liquid detergent
- √ Screwdriver

Remove the mirror from the sink and stand it on edge, using another towel to prevent slipping, and let it dry thoroughly. Letting it dry standing on edge allows excess water to run off the mirror. If you lay it on its back, "puddles" can form and leave water spots.

How to Clean Other Optical Surfaces

Mirrors aren't the only optical surfaces that need occasional cleaning. Refractor lenses and eyepieces can pick up a coating of dirt, especially if they are used often. (The methods are the same for each of these, since eyepieces are made up of little lenses.) I find it hard to keep eyepieces clean, especially when they get hard use at public observing sessions. They routinely pick up a good coating of finger grease. Cleaning eyepieces is a lot like cleaning mirrors, but on a smaller scale. Clean the lenses in place, rather than take the eyepieces apart and clean individual lenses. I can't count the number of times I have heard of amateurs who have disassembled an eyepiece only to discover they can't reassemble it the same way.

To clean your eyepieces, mix up a cleaning solution consisting of three parts distilled water to one part isopropyl alcohol. Add a drop of liquid detergent to each quart of solution. You can also use a lens cleaning solution like Mir-O-Len, available from Clausing Coatings, or a photographic lens cleaner like that distributed by Kodak. Use your compressed air blower to remove the large particles of dirt and dust. Then put a drop of your cleaning fluid on a cotton ball and lightly swirl it onto the surface of the lens. Don't place solution directly onto the lens element, or the fluid will seep into the lens housing. Use another cotton ball to clean the lens with a gentle circular swabbing motion and a third to dry the lens off.

Another type of optical surface that needs cleaning is a Schmidt-Cassegrain telescope's corrector plate. Your corrector plate is as easy to clean as an eyepiece. Begin by removing the heavy dust and dirt with a blower. After you have the big stuff off, get out your cleaning solution and cotton balls. Apply the solution directly to the cotton and start at the center of the plate. Use even strokes. Resist the temptation to put pressure on them, moving straight out from the center to the edge. Overlap your strokes and discard each cotton ball after completing a stroke. Use as many cotton balls as it takes to dry the plate.

Cleaning a telescope's optics is a duty too frequently neglected. Too many amateurs approach the subject as if they were disarming a nuclear device: *one false move and you're dead!* But like many things in this wonderful hobby, the process sounds more intimidating than it actually is. Cleaning a telescope's optics is no harder than cleaning your windows, as long as you take proper precautions and carefully follow instructions. Done correctly, maintaining your telescope's optics is a painless, straightforward process that will keep your telescope and eyepieces operating at peak efficiency. ☐

Michael Porcellino is an amateur astronomer living in Chicago, Illinois. His last article was "Astronomy in the Age of MTV" in the July 1991 issue.

Seeing the Most on JUPITER

There's lots to see on Jupiter this spring. Here's a guide to what your telescope will show.

By José Olivarez

March is a great time to watch Jupiter. As the month opens, the giant planet is conveniently placed in the evening sky and as close to Earth as it gets this year. Through a telescope, it presents the largest and most rewarding disk that we can see on any planet.

What can you expect to see? If you have a 2.4- to 3-inch telescope, you'll easily see Jupiter's slightly flattened disk streaked by an equatorial band or two. Don't bother with high magnification — 50x to 100x is all you need. However, the greater resolving and light-gathering power of a 6- or 8-inch telescope will allow you to use 150x to 200x and pick out some of the smaller and ever changing cloud features.

No matter what the telescope, when you examine Jupiter, the first features to strike the eye are the planet's dark belts (banded regions of low pressure) and bright zones (regions of high pressure). These stretch parallel to the equator. The dark belts are long-lived but they can fade away or intensify over time.

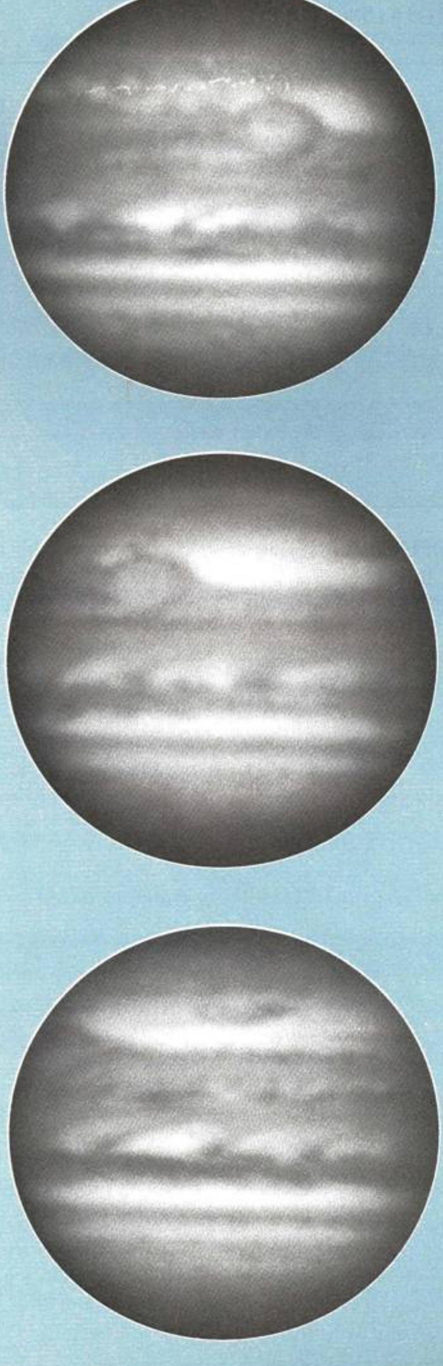
Jupiter's disk is divided into numerous bands and zones, not all of which are visible at any one time. Currently, the visible belts include the North Equatorial Belt (NEB), the South Equatorial Belt (SEB), the North Temperate Belt (NTB) and, close to the south pole, the South South Temperate Belt (SSTB).

You can sometimes glimpse the famous Great Red Spot embedded in the southern edge of the South Equatorial Belt. But depending on which side of the planet is facing Earth at the time you are looking, you may or may not see the Spot. Even when it is visible, the Spot can be difficult to pick out because it is now rather pale.

Overall, Jupiter's cloud bands are relatively quiet now compared to 1989 and 1991 when they underwent striking changes. Indeed, in July 1989, the world's astronomers were startled to discover that the South Equatorial Belt had vanished from view after more than a decade of prominence. Also, as if to make up for the loss of the SEB, the Red Spot darkened during the SEB's absence and appeared as a very well-defined orange ellipse during most of 1990. The SEB redeveloped in late 1990 and early 1991 and returned the face of Jupiter to its current "normal" appearance.

Tips for Seeing Detail

Although Jupiter's generous size and relatively well-defined belts and zones make it a rewarding target for any telescope, the type of telescope traditionally preferred by planetary observers is any well-collimated telescope with little or no central obstruction. And although 4- and 6-inch apertures can be used effectively by capable observers, a good choice for seeing lots of detail on Jupiter is probably an 8-inch aperture telescope. Because they have no obstructions in their light paths, refractors are highly regarded. A second choice would be a reflector

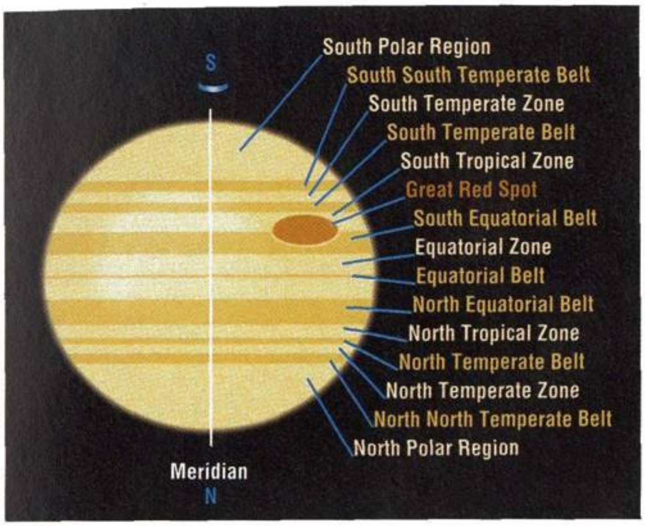


THREE VIEWS OF JUPITER show the rich detail that awaits observers. The top photo, taken January 24, 1991, shows the Red Spot and, at upper left, two of the southern hemisphere White Spots.

The middle photo, taken February 5, 1991, records a white expanse west (right) of the Red Spot.

In the bottom photo from March 7, 1991, the Red Spot is on the limb, and a White Spot called FA is at top center.

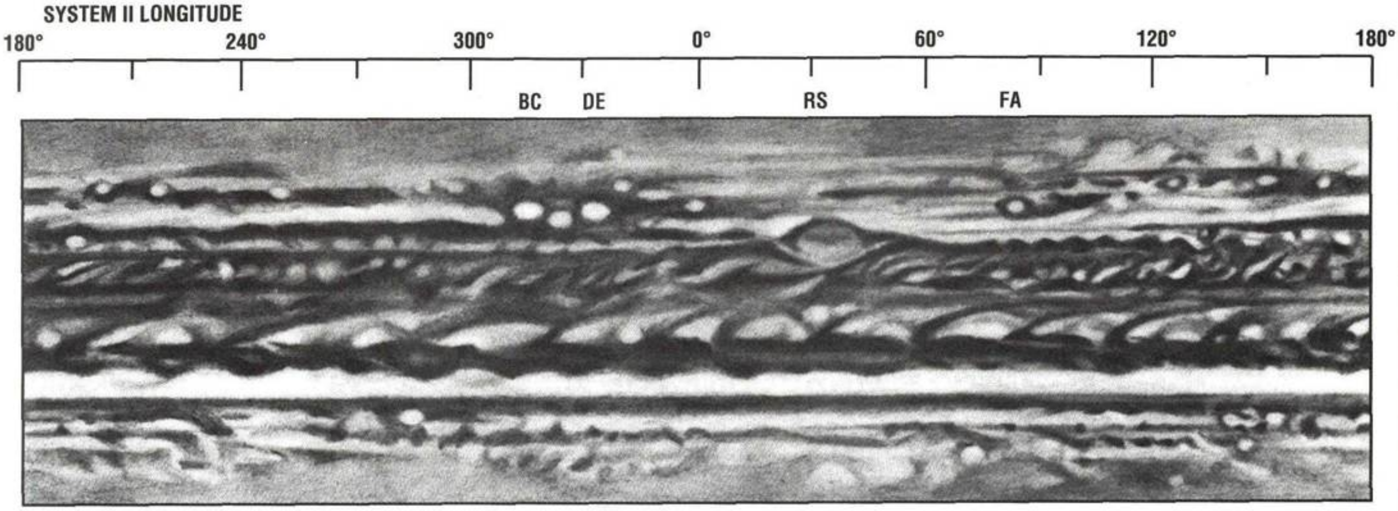
Photos by Isao Miyazaki with a 16-inch f/6 Newtonian at f/144 on Tech Pan film. South is at top and East to the left.



THE NAMING OF PARTS

Jupiter watchers soon learn to navigate through the technical terms for the planet's myriad features. In the standardized scheme, Jupiter's dark belts and bright zones alternate from the equator to the poles in this order: equatorial zone, equatorial belt, tropical zone, temperate belt, temperate zone, and polar region. Belts and zones are further specified by the hemisphere in which they appear.

Because Jupiter rotates faster at its equator than at latitudes closer to the poles, astronomers group these features into two separate rotation systems, called System I and System II. System I includes all of the Equatorial Zone and the adjacent south edge of the North Equatorial Belt and the north edge of the South Equatorial Belt. The rotation period of this region is 9h50m30s. All other latitudes north and south of System I belong to System II and rotate at 9h55m40.6s.



A COMPLETE JUPITER is shown in this remarkably detailed strip map compiled from observations made March 6-7, 1991, with a 16-inch reflector by Isao Miyazaki of Japan. It shows the location of the Red Spot (RS) and three major White Spots, BC, DE, and FA. Also note the diagonal festoons jutting south from the North Equatorial Belt and the turmoil of detail in the South Equatorial Belt.

whose secondary mirror can be made as small as possible. This keeps diffraction low and avoids undermining the already subtle contrast of Jupiter's features.

For the money, what's ideal is an 8-inch f/7 reflector with a well-figured mirror and a small diagonal whose major axis is less than 15 percent of the primary mirror's diameter.

A selection of filters will enhance the view through most telescopes. Filters can darken or lighten discretely colored clouds and improve the contrast between the belts and the zones. Filters I recommend for Jupiter's clouds are the Wratten #82A (very light blue), #38A (light blue), #25 (red), #12 (yellow), and #58 (green). The #82A, #12, and #58 filters will increase the contrast between the bright and dark features, while the #38A and #25 will help you distinguish between reddish and bluish clouds that are almost always present.

For observing Jupiter, or any planet for that matter, I prefer to use high-quality orthoscopic or Plossl eyepieces. Because Jupiter presents so large a disk, high powers are not necessary. Experienced observers agree that a power range of 150x to 250x is sufficient.

Red Spots and White Spots

The best known of Jupiter's long-lived cloud features is the Great Red Spot. Probably hundreds of years old, it may have first been seen by Giovanni Cassini in 1665. Thanks to spacecraft such as Pioneer and Voyager, we now know the Red Spot to be an anti-cyclonic, high-pressure bulge in the atmosphere. The Spot is a spinning mass of red clouds that takes six Earth days for one counter-clockwise turn.

This month, the Red Spot's center should lie near the Jovian longitude of 35 degrees in what is called the System II cloud bands. (See "The Naming of Parts" above.) But the Red Spot can move east or west in longitude and may not be at 35°. The motion of the Red Spot relative to the rest of the clouds is generally westward (in the direction of increasing longitude) but its motion can be erratic and unpredictable. To determine when the Red Spot is likely to be visible, turn to page 64 in the Sky Almanac section for a table of Red Spot transit times.

After the Great Red Spot, the second longest-lived features now active on Jupiter are the three white oval spots known cryptically as BC, DE, and FA. They are now situated near a latitude of 30° south, roughly the location of the now-faded South Temperate Belt. Being white, these spots don't stand out easily and are a challenge to see.

These White Spots first appeared in 1939 as extended brightenings in the South Temperate Zone. By 1947, however, they had the appearance of long shallow bays on the south edge of the South Temperate Belt. In the following 45 years, the bays have shrunk to ovals that today look like round white spots.

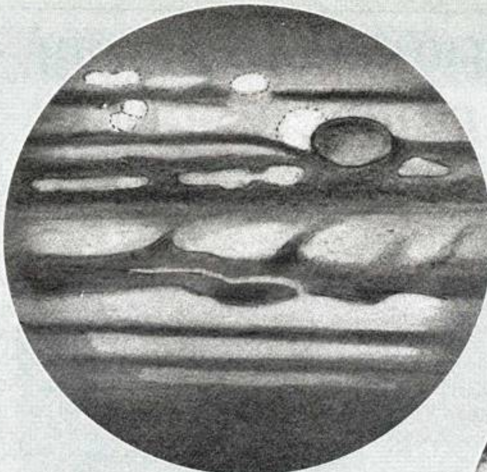
In recent years the spots have been difficult to see because the faded South Temperate Belt isn't dark enough to set them off. But White Spots BC and DE became briefly visible in March 1991 when a short-lived South Tropical Zone disturbance developed near them. White Spot FA was also visible through most of 1991 because it appeared attached to the eastern end of a dark segment of the otherwise missing South Temperate Belt. White Spots BC and DE, about 8 degrees long, have remained at this length for the last five years. Spot FA has shrunk to about 5 degrees in length and it may shrink out of existence before this decade is out.

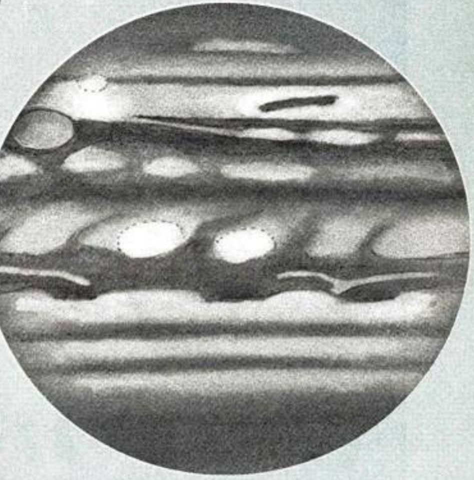
Blue Streaks at the Equator

Perhaps the most interesting features to look for near Jupiter's Equatorial Zone (EZ) are the blue spots and associated festoons (diagonal streaks). These lie along the southern edge of the North Equatorial Belt (NEB) at a latitude of 7° North. In fact, under close inspection all the dark protuberances extending equator-ward from the southern edge of the NEB are bluish. Because they are, a #25 red filter will darken these features and make them stand out.

The diagonal blue streaks are unique to the northern equatorial area of Jupiter and are all very similar. For example, all exhibit rotation periods are very close to System I's rate. This means they remain nearly stationary at the longitudes they occupy (they don't move east or west relative to surrounding clouds). The blue features are also all long-lived.

Usually 12 of the bluish festoons, more-or-less equally spaced around the planet, are visible at any one time. Infrared photography shows them to be thermal sources much warmer than their surroundings. This suggests they may be the tops of deep holes in Jupiter's atmosphere through which snowflakes and droplets of water vent upwards.





SKETCHING IS THE WAY to become familiar with the giant planet's offerings. The top sketch depicts Jupiter on April 12, 1991, at 19h15m UT. The bottom sketch, from April 10, 1991, at 19h12m UT shows a slightly different face of Jupiter. Compare these to the similar photos at top and bottom on page 85. Sketches by Jean Dragesco using a 7-inch refractor at 190x. South is at top.

Colors, By Jove!

Once you've bagged some of the long-lived cloud features try looking for color. Orange, brown, blue, and yellow hues, almost always present in Jupiter's clouds, appear distinct only with the aid of 10-inch and 12-inch telescopes. In smaller scopes, the colors are subtler and visible only on nights when the image is steady.

The dark belts are normally colored brown, orange-brown, blue, or lavender. The zones can vary from white to blue. A year ago the South Equatorial Belt looked orange-brown while the North Equatorial Belt changed from dark brown to a lavender-brown. The center of the Red Spot ellipse was pink. A temporary belt that developed at the latitude of the South Tropical Zone (but that has now disappeared) had a striking bluish color. Look for these colors with as large an aperture as you can. The blues and the lavenders will be the toughest to perceive.

Watching the Jovian Weather

Keep a close eye on Jupiter for the next few months and you'll see changes. For example, a disturbance consisting of dark festoons, dull veils, and bright oval spots may develop in the South Tropical Zone. If it does, it will be noticeable because the dark material will contrast with the white of the Tropical Zone. Also, if the disturbance occurs, it will most likely appear at longitudes just ahead of or just behind the Great Red Spot.

Elsewhere on Jupiter, short-lived white streaks, bright rifts, or white spots may appear in the North Equatorial Belt particularly at its interior. Along its northern edge watch for the growth of intense orangy brown dark spots.

Be sure to watch the active South Equatorial Belt and the Equatorial Zone. The EZ's southern half was dark and orange-colored in 1991 but could change coloration any time. Also look elsewhere for dark spots and brilliant white ovals that can develop without warning.

Consider submitting reports of your observations. Send them to the Jupiter Recorders of the Association of Lunar and Planetary Observers at 1469 Valleyview Court, Wichita, KS 67212. Send photos, drawings, and descriptions of Jupiter's activity. For those who want to start a program of Jupiter-monitoring, a "how-to" Jupiter Observing Kit is available for $8 from the above address.

Jupiter can provide hours of viewing pleasure. It rises conveniently around sunset each night this month, so now's the time to start. ☐

José Olivarez, director of the Omnisphere and Science Center in Wichita, Kansas, has observed Jupiter since 1960 and is Jupiter Recorder for the Association of Lunar and Planetary Observers.

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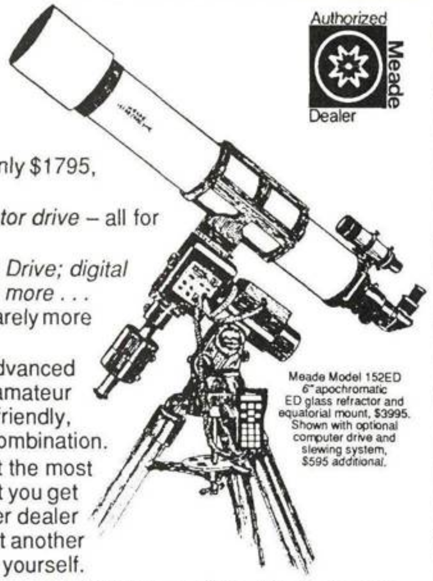

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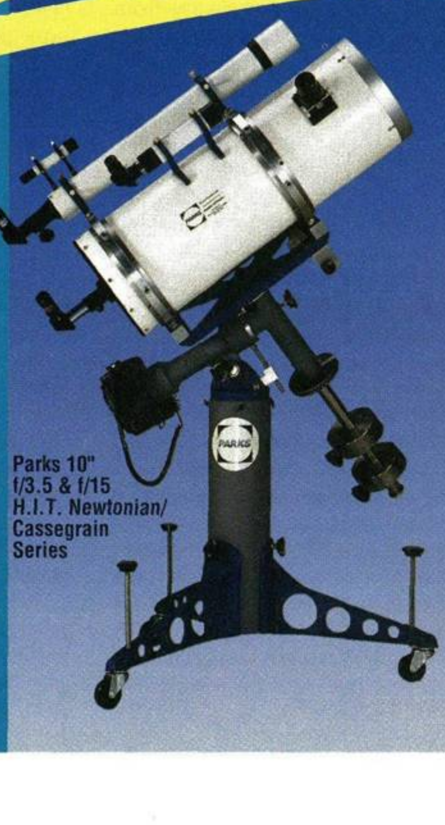

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NIGHT OF THE GREAT AURORA

"Dave, come outside right now and look up!"

With those words from my wife Lynda, I walked outside and was introduced to the greatest aurora I've ever seen. It was Friday, November 8, 1991, at about 7:00 p.m. One glance upward showed a sky blazing with lights — Lynda had noticed its brilliance as she drove home, watching it through the car's windshield. As we wandered farther into the yard and our eyes became dark-adapted, it was clear this would be no ordinary aurora.

The aurora at once appeared unusual because it was both big *and* bright. I had observed plenty of aurorae before, usually small, bright, active streamers or large, amorphous, static glows. The November 8 show began as a long streamer some 10° to 15° wide, stretching all the way across the sky from northwest to southeast, mostly gray-green and yellow in color but strongly orange and red overhead where it passed close to the zenith. Between 7:00 and 8:00 p.m. CST the aurora exploded in an incredible outburst that filled the entire sky with light, filling the sky overhead with coronal streamers that radially streaked away from a point near the zenith. The sky-bisecting band of light intensified and broadened, showing bright colors the likes of which I had never seen. At lower elevations in nearly all directions we saw bright eruptions of greenish curtains and sharply defined vertical rays. The outburst died down slowly after nearly an hour of a presentation so intense it looked like it was somehow artificial. The aurora went through a second outburst around 10:00 p.m., though it was not as dramatic as the earlier one.

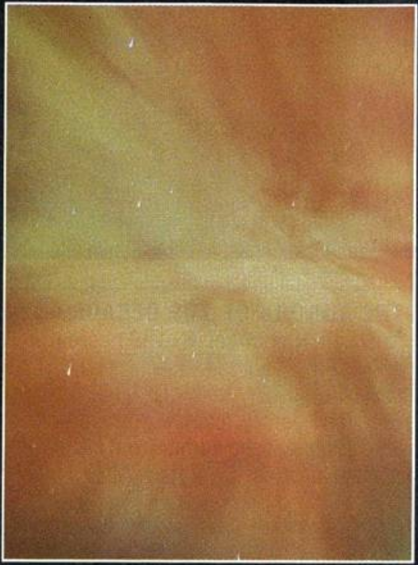
Many readers sent reports and photographs — so many it is impossible to publish anywhere near the number of photos we received that are nothing short of spectacular. "It was the most unusual aurora I've ever experienced," says Brenda Culbertson of Topeka, Kansas. "Pulsations created the effect of a sky on fire with periodic explosions in the distance." Nearby, in Louisburg, Kansas, Vic Winter recorded, "The vividness of the red colors in this aurora is incredible!" Paul Borchardt of Brookfield, Wisconsin, remarks, "In 20 years of stargazing I have never seen anything like it."

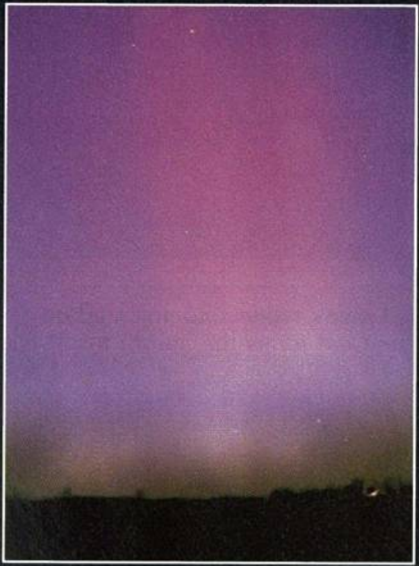
Many readers commented on the unusual forms the aurora displayed. Michael Henry of Massillon, Ohio, was awestruck by coronal arcs surrounded by rays and streamers that covered nearly the entire sky, creating a 360° panorama. Jay Brausch of Glen Ullin, North Dakota, viewed the peculiar pennants of light that hung down from the zenith during part of the show. Robert B. Slobins of Fort Lee, New Jersey, noticed a "great yellow ray that formed under Auriga and slowly spread out, stretching more than 20° across."

The aurora's intensity ensured southern observers a rare glimpse of a bright aurora. Reports from Texas, Alabama, Georgia, Oklahoma, and Mississippi documented the aurora's presence in the skies of the American south.

Of all the reports, Dick Fesenmeyer of the Iowa City Amateur Astronomers provided the most poignant. "The intensity of the aurora had a profound effect on many of us in Iowa City," he says. "As you know, the bright aurora occurred one week after a brutal series of shootings at the Van Allen building here at the University of Iowa, in which five staff members were killed and one grievously wounded by a disgruntled graduate student. Auroral research was the specialty of most of those killed, and so we feel that brilliant show was a remarkable natural tribute to the victims." — *David J. Eicher*

THE AURORA OF THE DECADE blazed forth on November 8, 1991, creating a light show so bright and colorful it appeared artificial. Robert B. Slobins of Fort Lee, New Jersey, captured these remarkable photos of the aurora from his observing site in Colesville, New York.





A GALLERY OF AURORA PHOTOS

The November 8 aurora produced a deluge of impressive photos — we wish we could print them all! Jim Baumgarten's 20-second exposure showing a lone tree silhouetted against the fiery sky (opposite page, top) wins this month's $100 "Best Astrophoto" award. Other spectacular shots included those by Vic Winter (left), Robert B. Slobins (above, right center), Greg Flanagan (above, left center), and Paul Woolsey (opposite page, bottom right).

Auroral shots depicting details included two images by Jay Brausch. The structures visible in these photos are pennants of greenish light hanging from a broad, ruddy glow (top left) and thin, parallel streaks of light (opposite page, bottom left).

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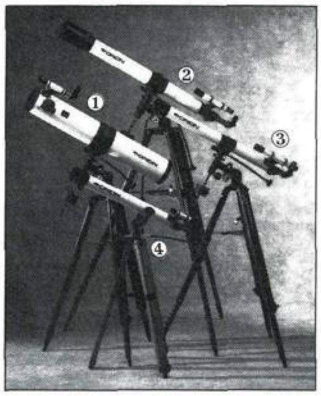

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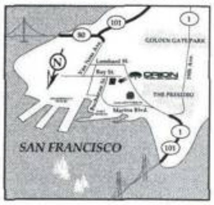

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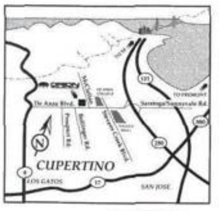

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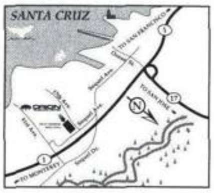

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Orion's Dew Zapper is a sure-fire cure for dew problems on your 8" or 10" Celestron or Meade Schmidt-Cassegrain telescope. Dew Zapper gently replaces lost heat, bringing the corrector plate temperature slightly above air temperature.

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DC Model #3503, AC Model #3504 **$44.95** (2.98)

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For Meade SC 10"	#5152	**$84.95**	(4.78)

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Primarily for astronomical use, lets you view at a right angle. Multi-Coated, for 1.25" eyepieces.
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Get the widest possible field of view from your Schmidt-Cassegrain Telescope. This star diagonal features a special aluminized and overcoated precision first-surface flat mirror.
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For high powered photography with your Meade, Celestron 4", 8", 10", 11", 14" Schmidt-Cassegrain.

Standard Tele-Extender
Use this Tele-Extender in conjunction with an eyepiece. Attaches to visual back of Meade or Celestron Schmidt-Cassegrain telescopes, and to 35mm camera with T-ring, sold separately.
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Standard Universal Camera Adapters
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FOR SALE — Parks mirror and diagonal, 8" f/6. Best offer or trade for 8" or 10" Odyssey, 80mm binoculars, or what you want to trade. Contact Todd Cardona, 8689-2 N. Ridge Ave., Berrien Springs, MI 49103.

FOR SALE — Meade DS-10A reflector with dual-axis drive corrector. Equatorial mount, accessory shelf, leveling screws/casters. 8x50 finder and 2" photo guide scope. Orion 2x Barlow and moon filter. 12/25 MA eyepieces and 7mm Ortho for 1.25". $850. Contact Rich Levenson, 14 Sandpiper Dr., Manalapan, NJ 07726. Phone (908) 446-7945.

FOR SALE — Positions as players in Rule the Universe, a strategic futuristic wargame in space. Travel over 2000 stars while controlling military, social and economic directives. Compete worldwide by mail. Send $1.00 for information. Contact G.F. Carbone, P.O. Box 8051, Wichita, KS 67208-0051.

WANTED — Thirty-seven-year-old Hungarian amateur astronomer would like correspondence with people worldwide who are interested in astronomy and philately, to help put together a collection in the history of astronomy and exchange stamps. Contact Istvan Farago, Kismartoni utca 87, H-2040, Budaors, HUNGARY.

FOR SALE — Digital sidereal clock with alarm. Includes instructions for setting local sidereal time. $79. Contact Jose Valdes, 10123 Boynton Place Cir., Boynton Beach, FL 33437. Phone (407) 736-9029 evenings.

FOR SALE — Celestron C4.5, Ortho 25mm and 9mm eyepieces, Barlow 2x, camera mount, shutter release, star charts. $500. Contact Tom, 1460 Heather Lane, Livermore, CA 94550. Phone (510) 443-1588.

WANTED — Twenty-two-year-old new amateur astronomer interested mainly in planetary science seeks correspondence with amateur/professional astronomers from western U.S. Contact Marc Conza, P.O. Box 1707, Ft. Myers, FL 33902.

FOR SALE — Original, fully detailed scale plan for 10-foot domed or roll-off observatory. $49.95 for either set. Contact John Hicks, Golf Road, P.O. Box 75, Keswick, Ontario L4P 3E1, CANADA. Phone (416) 476-3496.

FOR SALE — ASTRONOMY Magazine, 1990 and 1991. $18 one year, $35 both. Postage included. Contact Gary A. Libertore, 5103 Hamilton Ave., Baltimore, MD 21206.

WANTED — Nineteen-year-old seeks correspondence with young adults in U.S. or Canada who are interested in astronomy. Other interests include SF and horror films, computers and music. Contact Craig Wallington, 37/228 Beauchamp Rd., Matraville, NSW 2036, Sydney, AUSTRALIA.

FOR SALE — ASTRONOMY Magazine, 1974 and 1976-1981 in binders, and September 1982-August 1984 loose. *Sky and Telescope,* 1980-1981 in *S&T* boxes. All $125 plus postage. Contact Dan Brock, P.O. Box 15392, Baton Rouge, LA 70895-5392. Phone (504) 927-6707.

Astronomy Books

A STAR ATLAS FOR THE REFERENCE LIBRARY

Philip's Color Star Atlas: Epoch 2000, by John Cox and Richard Monkhouse, (Kalmbach, 1991), ISBN 0-913135-08-9, 40 pages, sewn binding, paperback, $19.95.

This is a large-format celestial atlas that can be used either outdoors (for naked-eye and binocular observing mainly) or indoors as a reference source. The heart of the atlas is a set of 20 sky maps or plates. These show the stars, color-coded by spectral type, against a pale blue background. The stars of both hemispheres are shown down to apparent magnitude 6.75.

The atlas also includes 12 additional charts that show selected regions in greater detail than the main maps do. These show areas such as the Pleiades cluster, the Southern Cross, Orion's Belt and Sword, and the Hyades cluster. Two circular all-hemisphere maps serve as keys to the 20 individual map plates. In the center of the atlas, two maps show the sky opened up and unwrapped. One plots the celestial equator as a horizontal line; the other does the same for the galactic equator. All these maps and charts are clear and easy to use.

Before the map section is a brief discussion of the electromagnetic spectrum, the Hertzsprung-Russell color-magnitude diagram, and stellar evolution. The main focus is on what we know about stars by understanding their colors. After the map plates, the text continues in a discussion of how stars "work," how the eye responds to star colors, and what the non-stellar objects are in the universe (galaxies, clusters, nebulae). In the middle of this part is a brief section that tells how to use the maps. (I think this should have been placed in a location easier to find.)

Novice users should be aware that because the authors have coded stars by their spectral type, the colors chosen for the map do not always match the colors perceptible to the eye. For example, O-type stars appear blue-white but are coded purple on the maps, and A-type stars look white yet are coded as green. The other star types, however, have colors similar to their appearance: type B is blue, F is light yellow, G is yellow, K is orange, and M is red.

In addition to color-coding, the hollow dots that represent each star have specific shapes to denote the star's luminosity class: circles are for main sequence stars, octagons for giants, hexagons for supergiants. Stars with peculiar spectral types are plotted as pentagons. Multiple and variable stars get their own symbols, as do open and globular clusters, nebulae, and galaxies. So you'll never be wondering what's what, a legend at the top of each map plate defines the symbols.

One feature I really like is that on the top outer corner of each map plate the authors have placed the map number surrounded by the map numbers of the adjoining plates. I've had to hand-annotate other star atlases because they lacked this kind of information. Another nice feature is that the maps show the common names of the brighter stars in addition to their designations, such as Bayer's Greek letters and Flamsteed's numbers.

The maps each take in lots of sky, which makes them somewhat difficult to use at the telescope. Because the maps give you the big picture, the scale occasionally makes for crowding in densely populated regions, hence the separate detail maps. With a limiting magnitude of 6.75, you'll be able to see nearly all the stars shown with the naked eye under a dark sky.

Overall, this is a good atlas for learning and exploring constellations and, used indoors, for helping you understand the intrinsic differences between types of stars. It should make a nice addition to your reference library.
— *Robert A. Garfinkle*

Cosmology & Astrophysics

Atoms, Stars, and Nebulae, by Lawrence H. Aller, (Cambridge University Press, 1991), ISBN 0-521-31040-7, 366 pages, paperback, $34.50.

Now in its third edition, this classic book on stars has been brought up to the 1990s. (Editions 1 and 2 came out in 1943 and 1971, respectively.) Aiming his book at the interested lay reader, Aller has written an excellent and detailed account of where stars come from, what makes them shine, how they evolve, and what happens when their lives have run their course.

Cosmic Time Travel, by Barry Parker, (Plenum, 1991), ISBN 0-306-43966-2, 308 pages, hardcover, $24.50.

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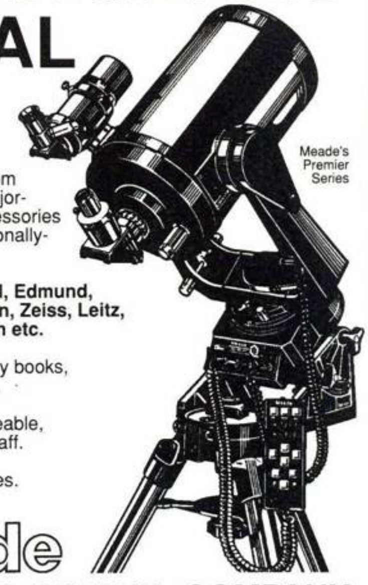

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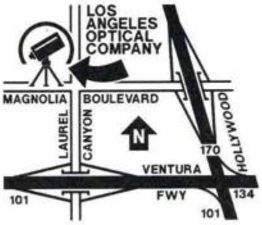

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ASLA9104 Astronomy - April, 1991

PRECISION SOLAR FILTERS

Thousand Oaks Optical solar filters are recognized around the world for their quality, consistent density and even coating across the entire aperture. We specialize in solar filters only and are the largest solar filter manufacturer in the world. Filters are available to fit all brands of telescopes and binoculars. **Thousands of our filters are in use around the world. The preferred choice of telescope dealers and exclusively used by NASA aboard the Space Shuttle.**

TYPE 1 - Made from high quality hand select glass, machine polished and **TRIPLE COATED** with a Nickel-Chromium alloy (same as Inconel). Mounted in a machined aluminum cell ready to attach to telescope. Solar image is yellow-orange. No secondary filtering is necessary.

TYPE 2 - Same as type 1, except stainless steel is combined in the coating to provide an even more durable surface that highly resists wear due to excessive handling and ultraviolet radiation. Solar image is also yellow-orange.

TYPE 3 - Coated to a neutral density of 4 for serious astrophotographers who desire the shortest possible shutter speeds with slow films. Solar image and optical quality same as type 1 and 2. Type 3 filters are for photographic use only.

Type 1 & 2 are for unlimited visual use and general photographic use. Instructions included with all filters, including tips on solar photography.

Our filters are many times more durable than common aluminized Mylar. Aluminized plastic cannot hold up to long term ultraviolet radiation and environmental contaminants as well as Nickel-chrome and stainless steel coated glass. Wrinkled Mylar can cause visual and photographic difficulties, can be easily damaged in handling or if placed on an uneven surface, and is difficult to clean. Also, a light blue solar image does not yield as much detail and contrast.

GLASS (Full Aperture) Type 1

Aperture	mounted:	Aperture	unmounted:
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3.1"	48.00	3.1"	38.00
3.5" to 4"	54.00	3.5" to 4"	44.00
5"	69.00	5"	59.00
6"	74.00	6"	62.00
8"	89.00	8"	76.00
10"	99.00	10"	89.00
11"	109.00	11"	99.00
12.5" to 13.1"	129.00	12.5" to 13.1"	109.00
14"	149.00	14"	129.00
40mm to 80mm Binoculars			$ 85.00 pr.

GLASS (Full Aperture) Type 2

Aperture	mounted:	Aperture	unmounted:
2.4"	$ 59.00	2.4"	$ 45.00
3.1"	62.00	3.1"	49.00
3.5" to 4"	72.00	3.5" to 4"	55.00
5"	92.00	5"	75.00
6"	99.00	6"	85.00
8"	119.00	8"	99.00
10"	129.00	10"	115.00
11"	149.00	11"	129.00
12.5" to 13.1"	169.00	12.5" to 13.1"	149.00
14"	189.00	14"	169.00
40mm to 80mm Binoculars			$109.00 pr.

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Aperture	mounted:	Aperture	unmounted:
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3.1"	80.00	3.1"	62.00
3.5" to 4"	94.00	3.5" to 4"	72.00
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ORDERING INFORMATION: Solar filters are shipped free in continental U.S. when payment is included with order. Shipping extra on credit card orders ($3 - $6 depending on aperture). Payment may be made by personal check, bank check or money order. We also accept **Visa, Mastercard** and **American Express. PLEASE SPECIFY TELESCOPE BRAND AND / OR OUTSIDE DIAMETER MEASUREMENT OF TELESCOPE TUBE.** The cost of the filter is based on the telescope aperture. The mounting cell fits over and around the end of the telescope tube. The coating faces the inside. Unmounted filters are the glass only.

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2 5/8" x 4 5/8" Overall size .... $2.00 ea.

Minimum order of 10 eclipse filters in any combination. Please add appropriate shipping / handling. 10 units: $3.00. Plus $1.00 for each additional 10 units. Minimum credit card order of $25.00. Quantity discounts available starting at 100.

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- Nontechnical talks by astronomers on new developments in astronomy, including the Hubble Space Telescope, the Magellan exploration of Venus, and the latest about black holes
- Introductory talks on getting started in astronomy
- Seminars and workshops for amateur astronomers
- An evening star party

Monday - Thursday, June 22-25

Further Conference programming will include:

- Tours of the Yerkes Observatory (with the world's largest refracting telescope) - Monday, June 22
- *The Universe in the Classroom*, A Workshop on Teaching Astronomy in Grades 3-12 - Tues. & Wed., June 23 & 24
- The Scientific Meeting of the A.S.P.- *Massive Stars: Their Lives in the Interstellar Medium* - June 23-25

Inexpensive accommodations and discount flights have been arranged for the meeting, which is open to everyone with an interest in astronomy. For more information, and a registration packet (available Spring 1992) write to:

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Write to: Jim Riffle, Hwy. 244, Box 608, Cloudcroft, NM 88317.

Parker has written an absorbing book that examines the possibilities for time travel. He shows that a careful reading of modern relativity theory shows that it could be possible — although he is strongly skeptical that the "loopholes" in the theory allow much in the way of practical application. This is a good book on an unusual subject that also teaches some relativity.

Reference Works

The Astronomy and Astrophysics Encyclopedia, edited by Stephen P. Maran, (Van Nostrand Reinhold, 1991), ISBN 0-442-26364-3, 1002 pages, sewn binding, hardcover, $89.95.

This encyclopedia contains over 400 articles on all topics relating to modern astronomy and its associated fields, such as planetary science. The book is arranged alphabetically, with headings chosen to place articles on related subjects together. For example, *Cosmology, Big Bang Theory* is followed by *Cosmology, Clustering and Superclustering.* The intended readers seem to be undergraduate students, which means that most interested lay readers will find the text accessible.

PPM Star Catalogue, compiled by Siegfried Röser and Ulricht Bastian, (Spektrum Akademischer Verlag, 1991), ISBN 3-86025-000-0, 1872 pages in 2 volumes, sewn binding, hardcover, DM 200 (about $130).

This catalog gives high-precision positions and proper motions for 181,731 stars lying north of –2°30' declination. The positions are given for epoch J2000.0. Each entry gives a running catalog number, BD number, photographic magnitude, spectral type, right ascension and declination, proper motion in both these coordinates, several measures of the positional reliability, and the star's numbers in the SAO, HD, and AGK3 catalogs.

CCD Astronomy, by Christian Buil, (Willmann-Bell, 1991), ISBN 0-943396-29-8, 321 pages, sewn binding, hardcover, $24.95.

This book is for any technically minded amateur astronomer who wants to assemble a CCD camera for astronomical imaging. The author explains how a CCD chip works and about the electronics required to run the camera. Then comes cooling the chip, operating the camera, and processing the images. The level of presentation assumes the reader is familiar with basic electronics and comfortable with equations and programming. ☐

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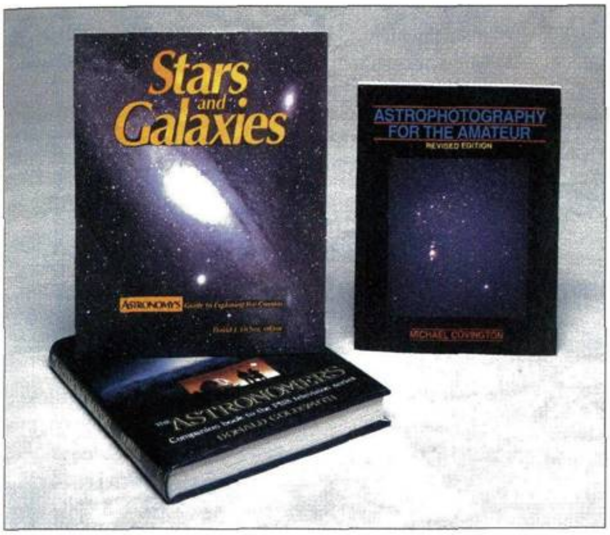
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INTERMEDIATE

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FOR SALE — *Cambridge Atlas of Astronomy,* 430 pages, fully illustrated, hardcover. $35 plus shipping. Phone (303) 666-8713.

Astrobytes

TS-24 TELESCOPE SIMULATOR

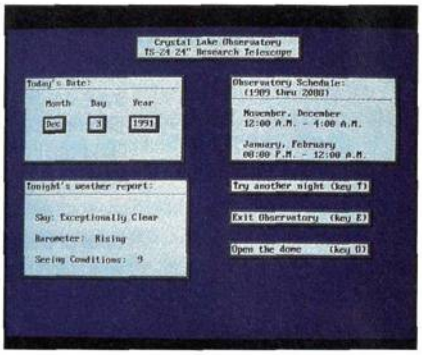
TS-24 Version 2.0*, Santa Barbara Instrument Group, 1482 East Valley Road, Suite 601, Santa Barbara, California 93108. Phone (805) 969-1851. $149 for site-registered software, Hands-On Universe Workbook $19.95. Available for IBM-XT compatible (with CGA or better) or Macintosh computers. No additional equipment is required.*

Crystal Lake Observatory, in conjunction with the Santa Barbara Instrument Group, has developed a telescope simulation program and workbook series aimed at high school students. Based upon my experience in teaching introductory astronomy at a large university, I think TS-24 would also be a useful addition to many college astronomy labs. The software is ideal for schools that do not have access to telescopes or need to run an astronomy lab during the day. As the authors point out, the exercises also could be used as part of an Earth science course.

TS-24 simulates a 24-inch telescope and its auxiliary equipment. Students start the program by entering the date. After receiving a randomly generated forecast about sky clarity and seeing, they may decide to open the dome or try another "evening." The program currently shows only a small piece of the sky, but it is sufficient for the stellar photometry that forms the backbone of the workbook.

The sky is a section of the constellation Gemini about 5° square, but it appears not to be a representation of the actual sky. The star cluster that appears prominently in the TS-24 simulated eyepiece does not appear, for example, in *Uranometria 2000.0.* However, this program is not meant to be a planetarium program. Rather, it shows students how science is done with a telescope. Since it accomplishes this goal quite well, the actual sky map it uses is not really important.

After the dome opens, the user sees an eyepiece view of the sky centered on the screen. The keyboard cursor pad controls the movement of the telescope while the function keys change eyepiece focal length, turn on the eyepiece crosshair, change telescope slewing speed, print a help screen, and install the auxiliary equipment. The user may choose from a photometer, a CCD camera, and automatic photometry.

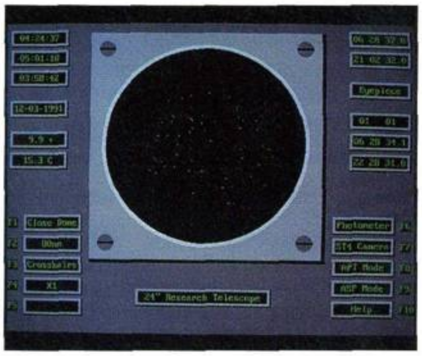


Crystal Lake Observatory
TS-24 24" Research Telescope

Today's Date:
Month Day Year
Dec 3 1991

Observatory Schedule:
(1909 thru 2008)
November, December
12:00 A.M. - 4:00 A.M.
January, February
08:00 P.M. - 12:00 A.M.

Tonight's weather report:
Sky: Exceptionally Clear
Barometer: Rising
Seeing Conditions: 9



The Hands-On Universe Workbook provides some basic information about motions of the night sky and astronomical coordinate systems and describes four main student projects. The first project shows how Earth's atmosphere affects stellar brightness and has the student observe the changing brightness of a Mira-type variable star. Project two is a search to find an asteroid and a determination of the asteroid's size from occultation timings.

Students count stars in different parts of the sky and find the colors and temperatures of stars in project three. The final project explores the nature of a star cluster. Students construct a color-magnitude diagram from their photometric measurements. Then they find the age of and distance to the cluster from their color-magnitude diagram. Advanced project ideas also are included for each project in order to challenge interested students.

The only major problem with the workbook is that it sometimes concentrates the student's effort on performing the measurement and not on the astronomy, which is the point behind doing the measurements. Too often, the science is left for the advanced projects. As an example, the star count exercise stops after the student finds average star counts in different parts of the sky. The student never really explores what this means. Perhaps the authors could expand the exercise to have students use their star counts to understand stellar distribution in the Milky Way Galaxy and how the distribution reveals the disk shape of the Galaxy.

I really enjoyed using TS-24 and think that students will find this program exciting. The software permits students to be participants in the scientific process and not spectators. It lets students explore the sky using simulations of equipment that many schools cannot afford. It also provides a means of filling a scheduled observing session that has been clouded out. I hope that the authors will produce additional workbooks in the series and add to the sky visible with TS-24. — *Dave Bruning*

NEW PRODUCTS

Distant Suns™ Windows™*, Virtual Reality Laboratories, Inc. 2341 Ganador Court, San Luis Obispo, California 93401. $129.95. Minimum requirements: MicroSoft Windows 3.X, 80286 or higher processor, EGA or higher, and* $5^1/_2$ *MB of available storage space on a hard disk. 1.2 MB* $5^1/_4$" *diskettes are included, but a swap coupon for* $3^1/_2$" *diskettes is enclosed.*

This Amiga program is now available for use on IBM-AT-compatible computers equipped with Windows. The object database includes 9,100 stars, and 450 galaxies, nebulae and star clusters. For a list of the other capabilities of this planetarium-type program, see the October 1991 Product Reviews.

Astronomy Lab for Windows 3.X™*, Personal MicroCosms, 8547 E. Arapahoe Road, Suite J-147, Greenwood Village, Colorado 80112. $59.95 plus $2.95 for shipping. Minimum requirements: MicroSoft Widows 3.X, 1 MB of available memory, and a mouse. Both 1.2 MB* $5^1/_4$" *and 720 KB* $3^1/_2$" *diskettes are provided. 360 KB* $5^1/_4$" *diskettes are available free of charge upon purchase of software.*

Astronomy Lab, as described in the April 1991 Product Reviews, is now available for Windows. This software produces animated movies of celestial objects and their motions, generates graphic representations of sky activity, and prints calendar-style reports about astronomical events. ☐

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STANDARD PACKAGE **$997.95**

SUPER POLARIS C8
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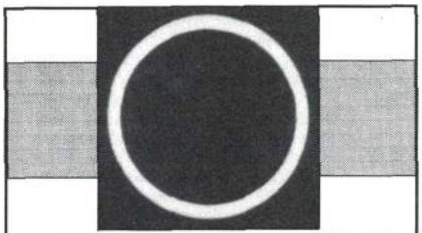

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1
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Panoptic Eyepieces from Tele Vue

Available in 35mm and 22mm focal lengths, these new eyepieces yield a 68° apparent field of view with an edge-of-field performance said to be significantly better than the performance of the Tele Vue 40mm Wide Field eyepiece. Eye relief on both models is sufficient to allow users to wear eyeglasses and still see the entire field. Both models are multi-coated and feature blackened lens edges, filter threads, rubber grip rings, and eyeguards. The 35mm has a 2-inch barrel and the 22mm a dual 2-inch/1.25-inch barrel. When used with Tele Vue's 2-inch Big Barlow, the matching Interface Lens is recommended to prevent vignetting and to optimize field correction even further.

Tele Vue Optics, Inc., 20 Dexter Plaza, Pearl River, NY 10965, (914) 735-4044, FAX (914) 735-4112. 35mm Panoptic: $475, 22mm Panoptic: $355, Interface Lens: $130.

2 Unitron Reintroduces Its 2.4-inch Refractor

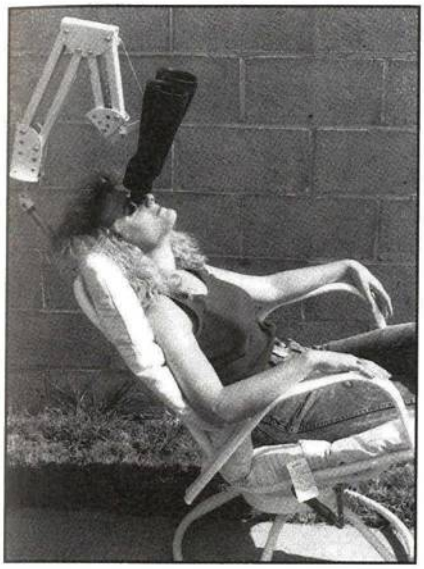
This 60mm f/15 refractor features a 900mm focal length, 6x23.5mm finderscope, rack and pinion focuser, Sun projection screen, dewcap, and 5 coated eyepieces: 7mm (129x), 9mm (100x), 12.5mm (72x), 18mm (50x), and 25mm (36x). The equatorial mount has slow-motion controls on both right ascension and declination axes, setting circles, tripod and leg brace with accessory shelf, and provisions for attaching an optional motor drive. A wooden case is standard.

Unitron Inc., 170 Wilbur Place, P.O. Box 469, Bohemia, NY 11716, (516) 589-6666, FAX (516) 589-6975. $1,125. Optional motor drive: $235.

3 New Unitron Binoculars

The new Unitron Pro Series includes 8x32, 7x42, 8x42, and 10x42 binoculars. Each features fully coated optics (including UV coating on the objective lenses and multicoated eyepiece lenses), porro prisms of BAK-4 glass, extra-long eye relief, rubber eyecups, rubber objective bumpers, tripod socket, case, and neck strap.

Unitron Inc., 170 Wilbur Place, P.O. Box 469, Bohemia, NY 11716, (516) 589-6666, FAX: (516) 589-6975. All models $260 except 10x42, which is $270.



4 The Celestial Observing Chair

The Vista Instrument Company's binocular chair (dubbed the Celestial Observing Chair) swivels 360° and can tilt to view the sky from horizon to zenith. The chair rocks back and can lock at any desired viewing angle. The binocular arm swings to the right or left to allow for easy access to the chair and forward or backward to allow for placement of the binoculars in front of the user's face. The chair is constructed of aluminum and steel and weighs 35 pounds. The spring-tensioned mechanical arm is designed to carry binoculars up to 100mm aperture, provided they have ¼-20 tripod threads.

Vista Instrument Company, 307 E. Tunnell Street, Santa Maria, CA 93454, (805) 922-2545. $450 plus shipping and handling.

5 Products for Children: Planetarium Mobile

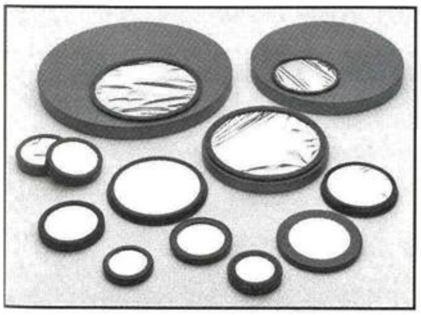
Nite Delites offers a glow-in-the-dark solar system mobile that consists of large plastic representations of the Sun, the Moon, and 9 planets. An adhesive wall kit version is also available. Both come with information booklets. Also available are large glow-in-the-dark adhesive stars and star stickers.

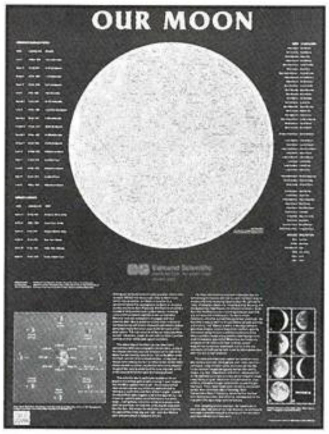
Nite Delites, Inc., 3726 South Peoria Avenue, Tulsa, OK 74105. Solar System Mobile: $21.99, Solar System Wall Kit: $19.99, Glow-in-the-Dark Stars: $5.95 for package of 10, Glow-in-the-dark Stickers: $6.95. Add $1 postage and handling per order.

6 Celestron Solar Filters

Celestron has added several new models of solar filters to its line, including a pair designed for 80mm binoculars. Celestron now offers 12 models to fit instruments from 80mm binoculars to its C14 telescope. All filters are made of two layers of Solar Skreen® Mylar and transmit only 0.0001 percent of visible light while blocking 99.9999 percent of invisible infrared light.

Celestron International, 2835 Columbia Street, Torrance, CA 90503, (800) 421-1526 or (213) 328-9560, FAX (213) 212-5835. Prices from $60 to $220.





7 Edmund Scientific's Moon Map

This full-color 24" by 32" poster provides a 14.5"-diameter map of the lunar surface visible from Earth. Prepared by cartographer Antonín Rükl, the map identifies all major lunar features and manned landing sites. The chart also contains Latin names, information about lunar phases, and lunar viewing suggestions.

Edmund Scientific Company, Dept. 11B1, N964 Edscorp Building, Barrington, NJ 08007. Varnished poster stock: $9.95, Kimdura plastic stock: $14.95.

READER'S EXCHANGE

ANNOUNCEMENT — The Ancient City Astronomy Club, Inc., meets the first Friday of each month at 8 pm in First United Methodist Church at King and Riberia Streets in St. Augustine, FL. Write to P.O. Box 546, St. Augustine, FL 32085-0546. Phone (904) 797-5704 or (904) 471-3054.

WANTED — Small, unmounted lenses, single element or doublet, up to 30mm diameter. Send list to Smith, 385 Allison Rd., Murfreesboro, TN 37130.

FOR SALE — Tasco 4.5" reflector 900mm F.L., many mods. Includes 12mm Celestron eyepiece, 2x Barlow, 7x50 finder, equatorial mount, moon and nebula filter. $375. Contact Anthony Showe, 3252 W. L-6, Quartz Hill, CA 93536. Phone (805) 943-4964.

FOR SALE — ASTRONOMY, August 1973 to present in volume files/binders. $325 plus postage. Contact Edward Ostrenga, 19 Pond St., #3 Side, Pawtucket, RI 02860. Phone (401) 728-1202.

WANTED — Eighteen-year-old amateur would like to correspond with other young amateur astronomers. Contact Illeana M. Diaz, 8306 Valley View Dr., El Paso, TX 79907.

FOR SALE — Back issues of PASP (1968-88), ALPO, KOZMOS, IAPPP, AAVSO journals; Astronomical Almanac, 1970-83; Annual Review of Astronomy & Astrophysics, 1963-82. Write for price list. Contact Clifford Cunningham, 250 Frederick St., Apt. 1707, Kitchener, Ontario N2H 2N1, CANADA.

WANTED— Data-processing student interested in amateur astronomy wants to correspond with American amateur astronomers. Contact M. Marouf Karim, Rue 21 Villa 8 Beaulieu, 16270 Algiers, ALGERIA.

FOR SALE — 8" f/6 Cave Newtonian, rotating rings, equatorial mount with RA and Dec electric drives, 8x50 finder and Meade 60mm refractor guidescope. $500. Contact J. Sproat, 46045 Fourth Ave., Chilliwack, B.C. V2P 1N2 CANADA.

FOR SALE — Giant binoculars, 5" f/3.5 objectives with 3-mirror systems, wooden cases and mounts. $300, FOB Charlotte, NC. Contact D. Weiss, 7305 Reynard Ln., Charlotte, NC 28215. Phone (704) 531-7200.

FOR SALE — Tasco refractor, including 2x Barlow and finder. $90 or offer. Contact James Clem, Rt. 1 Box 316, Branch, AR 72928. Phone (501) 965-7525.

WANTED — Thirty-six-year-old woman interested in astronomy, geology, travel, photography, music and communication skills wishes to correspond with others worldwide. Contact Joan Barnett, 158 Alpine Dr., Goleta, CA 93117-1344.

FOR SALE — Four CCD imagers complete with matched remote-control monitor, variable-magnification 1-1/4" optical system and power supply. $295 each. Contact Cindy Choate, 104 View St., Dracut, MA 01826. Phone (508) 458-8857.

FOR SALE — Criterion 8" f/10 Dynamax SCT, including drive, full tripod, wedge, case, level, many accessories. Asking $700. Phone (914) 561-8956.

FOR SALE — A3-P Planetarium projector. Contact Shiras Planetarium, 1203 W. Fair Ave., Marquette, MI 49855.

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FOR SALE — *Kimmel's Klingon Recipes.* $8.00. Contact *Kimmel's Klingon Recipes*, 1231 Garfield Road., Havertown, PA 19083.

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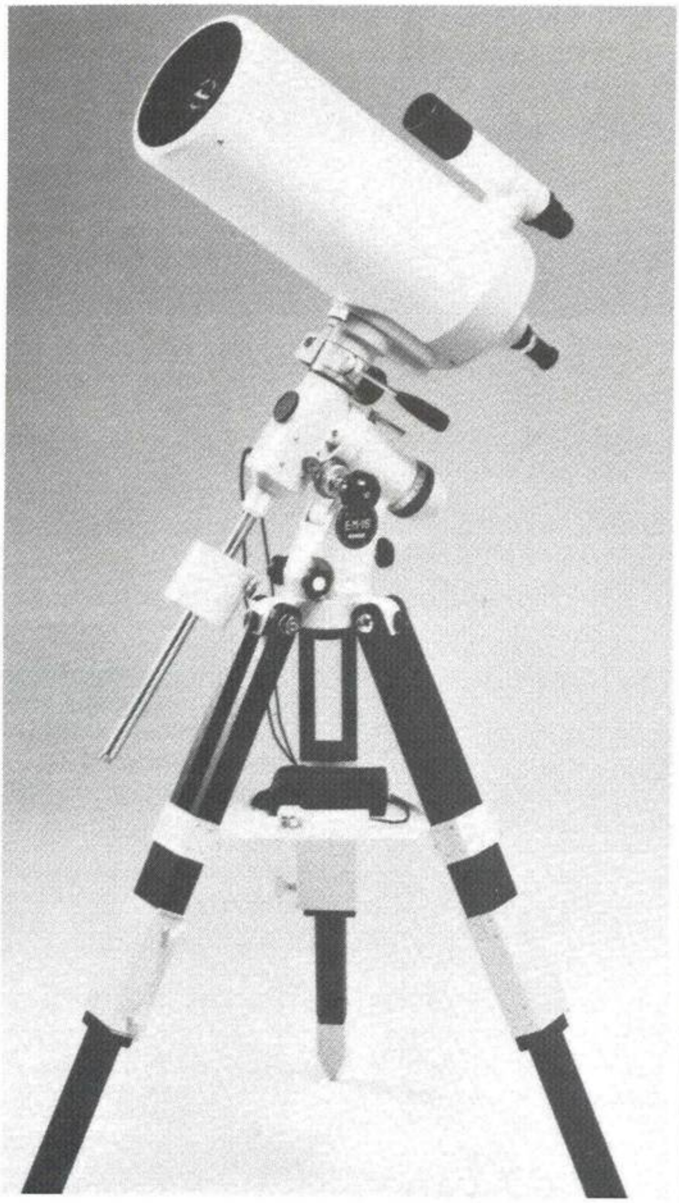

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Meetings & Events

March 14
Northwest Astronomy Form/Expo, Rockland Community College, Suffern, New York. Contact: Allan Green, 110 Pascack Raod, Pearl River, NY 10965.

May 9
Astronomy Day. Contact: Gary Tomlinson, Astronomy Day Coordinator, Public Museum of Grand Rapids, 54 Jefferson SE, Grand Rapids, MI 49503. Phone: (616) 456-3987.

May 9
Custer Institute Family Astronomy Day, Southold, New York. Contact: Warren Hamburger at (516) 888-0072 or Barbara Lebkuecher at (516) 722-3850.

June 6-7
7th Annual Sedona-Verde Valley Astrophotography Festival, two hours from Phoenix, Arizona. Sponsored by Rainbow's American Dream. Contact: Russell Nidey, 1101 Zalesky Road, Cottonwood, AZ 86326. Phone: (602) 634-7332.

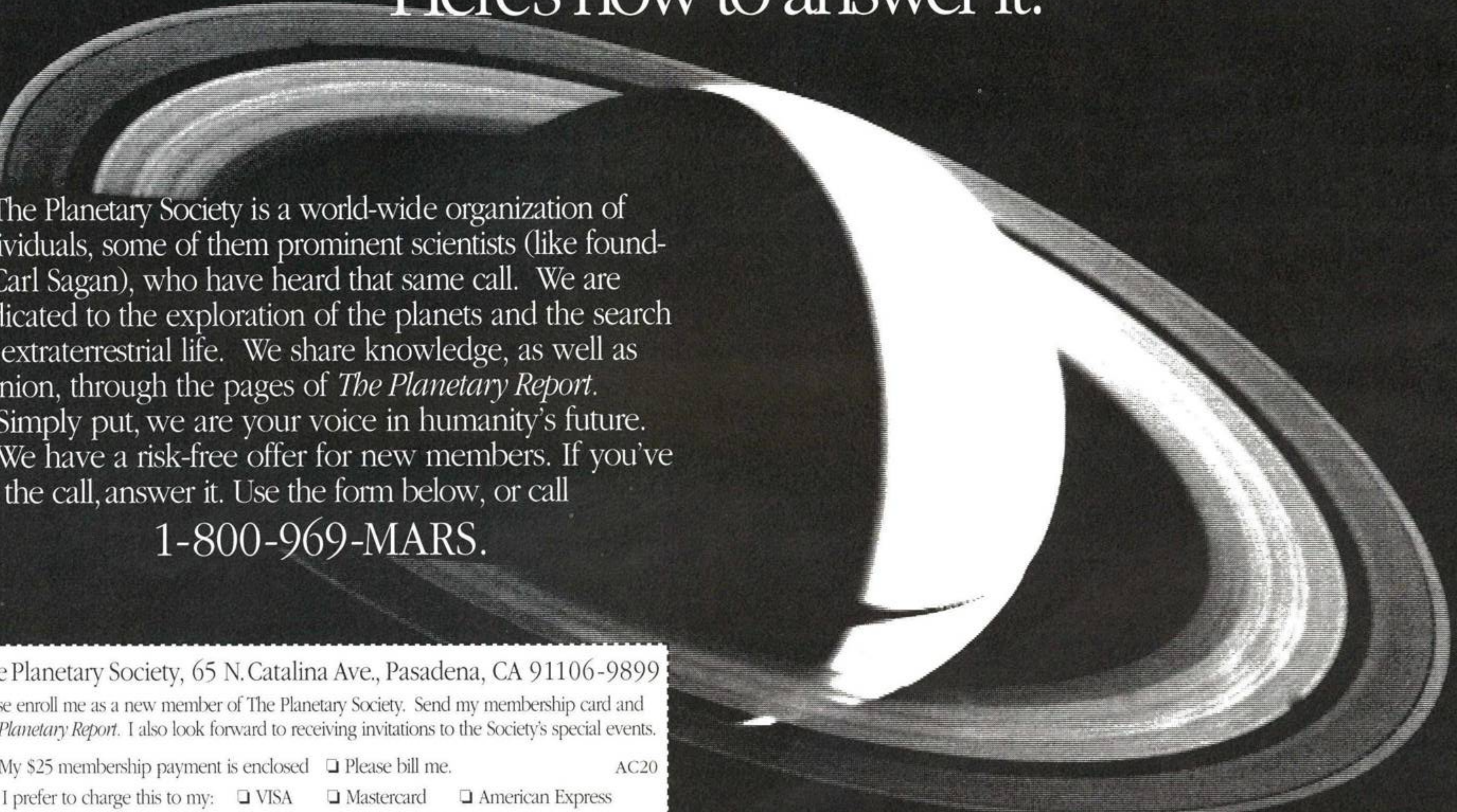
June 19-21
Astronomical League Mid-States Regional Convention, Avila College and Powell Observatory, Kansas City, Missouri. Sponsored by the Astronomical Society of Kansas City. Contact: Jackie Wade, M-S Chairman, 11305 King Street, Overland Park, KS 66210. Phone: (913) 469-0135.

June 20-25
Universe '92, A National Astronomy Expo and Conference featuring non-technical talks, exhibits and displays, and seminars and workshops, University of Wisconsin, Madison, Wisconsin. Presented by the Astronomical Society of the Pacific and ASTRONOMY magazine. Contact: Wisconsin Meeting Information, Astronomical Society of the Pacific, 390 Ashton Avenue, San Francisco, CA 94112. Phone: (415) 337-1100.

September 18-21
Meeting of European (and International) Planetary and Cometary Observers, Violau, Germany. Contact: Wolfgang Meyer, Martinstrasse 1, D-(W)1000 Berlin 41, Germany. □

Please submit announcements at least four months before the date of the meeting or event.

When you write to organizations listed in Meetings and Events, include a self-addressed, legal-sized envelope with your request for information.



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ANNOUNCEMENT — The Texas Astronomical Society of Dallas now meets at 8 pm on the fourth Friday (except December) in the Richland College Planetarium (Science Building), 12800 Abrams Road. For information, phone 964-2233 or 517-6980.

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ANNOUNCEMENT — Anyone in the Spring, Texas, area interested in forming an astronomy club, contact Dan Harriman at (713) 443-3750.

WANTED — Correspondence with other amateur astronomers. Particularly interested in new developments in astronomy and the NASA space program. Contact Ian Kahler, 4650 Sierra Madre, #843, Reno, NV 89502.

WANTED — Correspondence with other teenagers interested in astronomy, science fiction movies, UFOlogy, etc. Contact Marty Lee, P.O. Box 1164, 88812 Kota Kinabalu, Sabah, MALAYSIA.

WANTED — Fourteen-year-old boy who belongs to the tribe of Wassa wants pen pals; also donations of science textbooks and other items to help in school. Contact Kofi Kwando, Nkroful Agricultural Secondary School, P.O. Box 4, Nkroful, Ghana, AXIM.

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TELESCOPES

Vixen #9117 Telescope

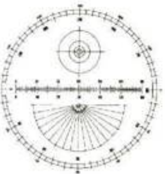
#9117 4½" Newtonian with Equatorial Mount

- 900mm fl, f/7.9
- 2 eyepieces –18mm (50X) –8mm (112x)
- 6x30 Finderscope
- Adjustable Aluminum Tripod **329^{95}**

#9115 4½" Newtonian Alt-Azimuth Mount

- 900mm fl, f/7.9
- 2 eyepieces –18mm (50X) –8mm (112x)
- 6x24 Finderscope
- Adjustable Aluminum Tripod **294^{95}**

Celestron's New Micro Guide Eyepiece



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Guiding with conventional dual-crosshair reticles often forces the user to slightly defocus the guide star to prevent it from suddenly being "hidden" behind the broad grooves - greatly reducing the limited magnitude. Due to the finely etched lines in the Micro Guide, much fainter, sharply focused star can be "captured" as guide stars with no reduction in limited magnitude. **139^{95}**

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Readings & Resources

Best Black Hole in the Galaxy (page 30)

Frozen Star by George Greenstein (Freundlich Books, 1983) is an older, but still excellent book that discusses the nature of black holes and the astronomers that study them.

The Life and Death of Stars by Donald A. Cooke (Crown Publishers, Inc., 1985). The life history of stars, from how they form to how some stars become black holes.

Fire in the Sky (page 38)

Aurora Borealis: The Amazing Northern Lights by S.I. Akasofu (Alaska Geographic, 1979). A well-illustrated booklet about the history and physics of aurorae by one of the top aurora researchers.

The Aurora: Sun-Earth Interactions by Neil Bone (Ellis Horwood, 1991). A new book all about northern lights.

Majestic Lights by Robert H. Eather (American Geophysical Union, 1980). A large format, well-illustrated book. A must for aurora fans!

Going Deep For Galaxies (page 68)

Burnham's Celestial Handbook by Robert Burnham, Jr., (Dover Publications, 1978). A three-volume compendium of data on deep-sky objects.

Atlas of Deep-Sky Splendors by Hans Vehrenberg, (Cambridge Universiry Press, 1983). A beautiful picture book of full-page plates that show hundreds of deep sky obejcts to the same scale for easy comparison.

Seeing the Most on Jupiter (page 85)

The Planet Jupiter by Bertrand M. Peek (Faber and Faber, London, 1958, revised 1981). A classic work that compiles pre-spacecraft observations of Jupiter and serves as the standard handbook for Earthbound Jupiter watchers.

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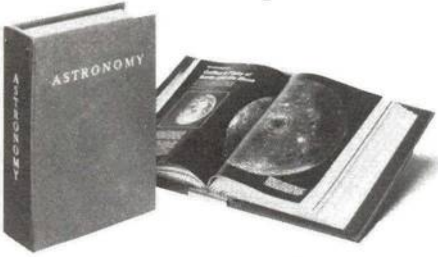

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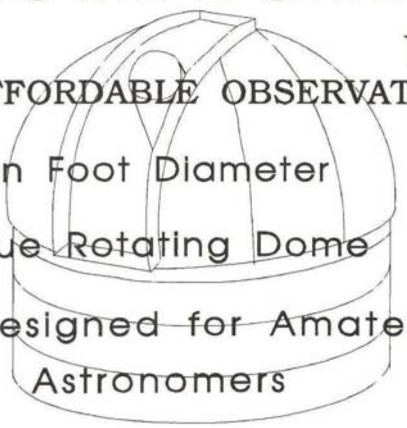

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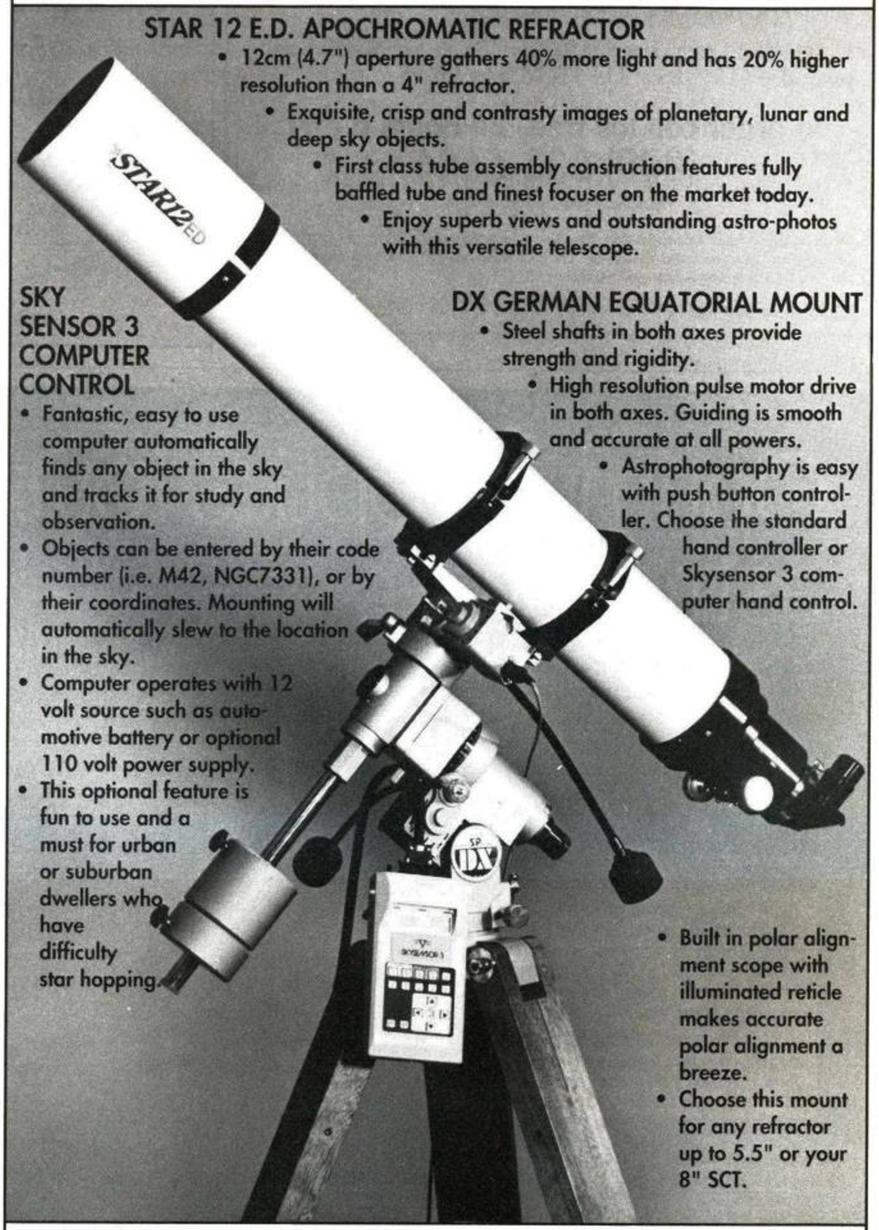

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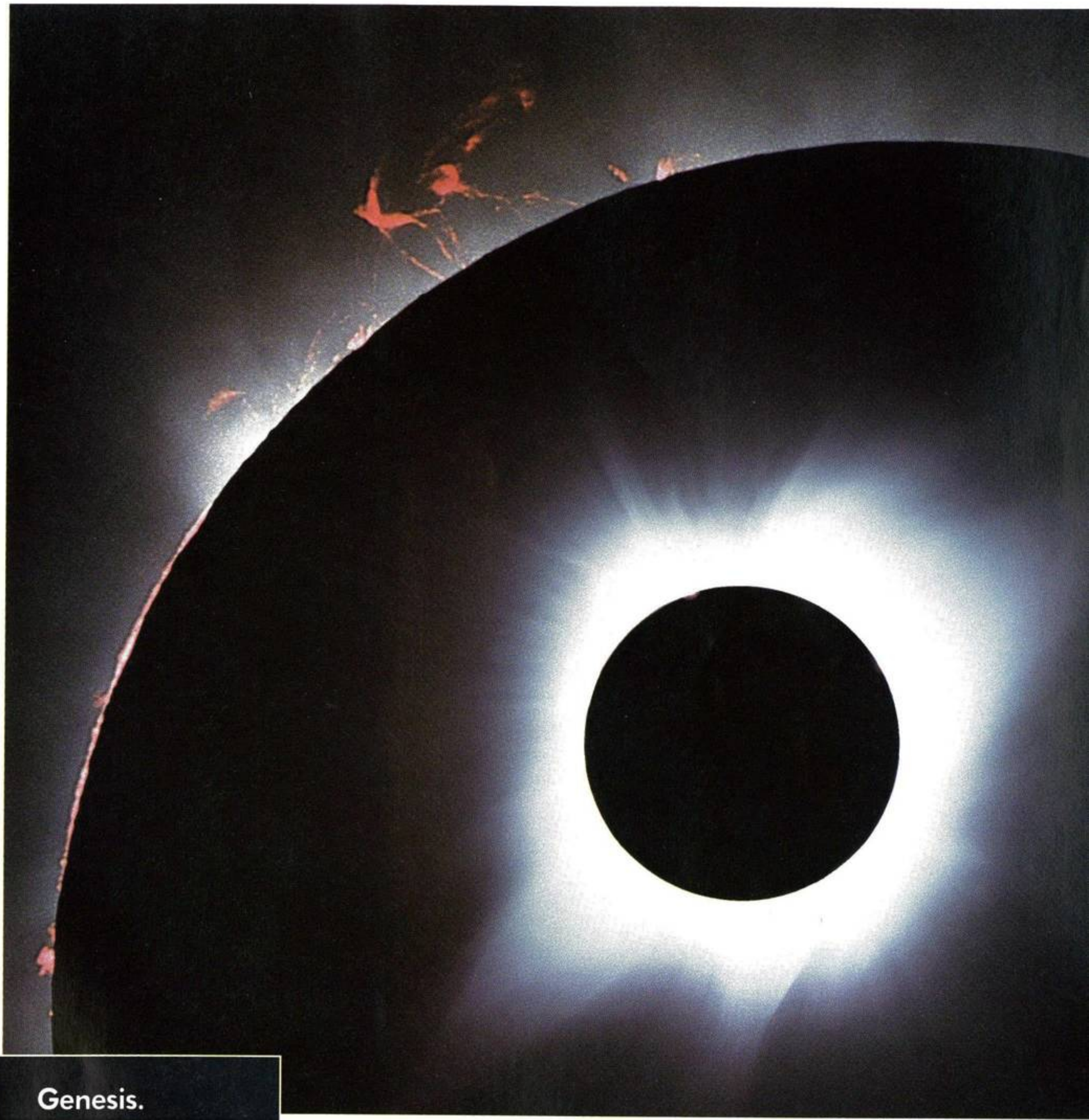

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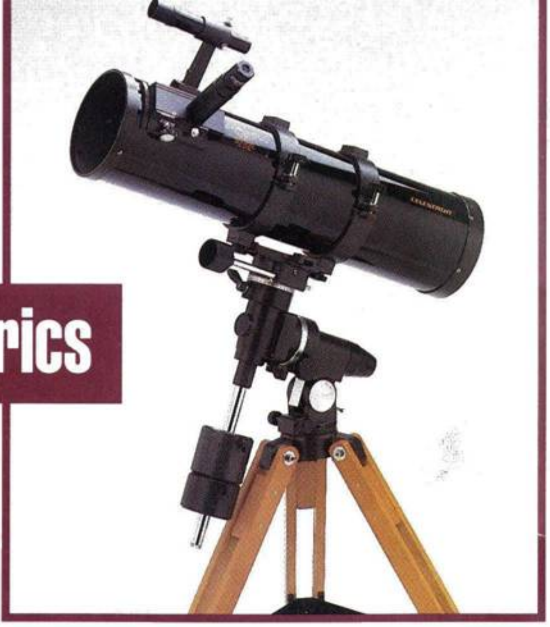

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